BROOKHAVEN NATIONAL LABORATORY

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FY 2003 – FY 2007

DECEMBER 2002

Brookhaven Science Associates, LLC
Upton, New York 11973

BROOKHAVEN
NATIONAL LABORATORY

managed by Brookhaven Science Associates for the U.S. Department of Energy

Institutional Plan

FY 2003 -- FY 2007

December 2002

Brookhaven Science Associates, LLC
Upton, New York 11973

BROOKHAVEN NATIONAL LABORATORY
Departments, Divisions and Offices

BROOKHAVEN NATIONAL LABORATORY
Operated by
BROOKHAVEN SCIENCE ASSOCIATES
FOR U.S. DEPARTMENT OF ENERGY
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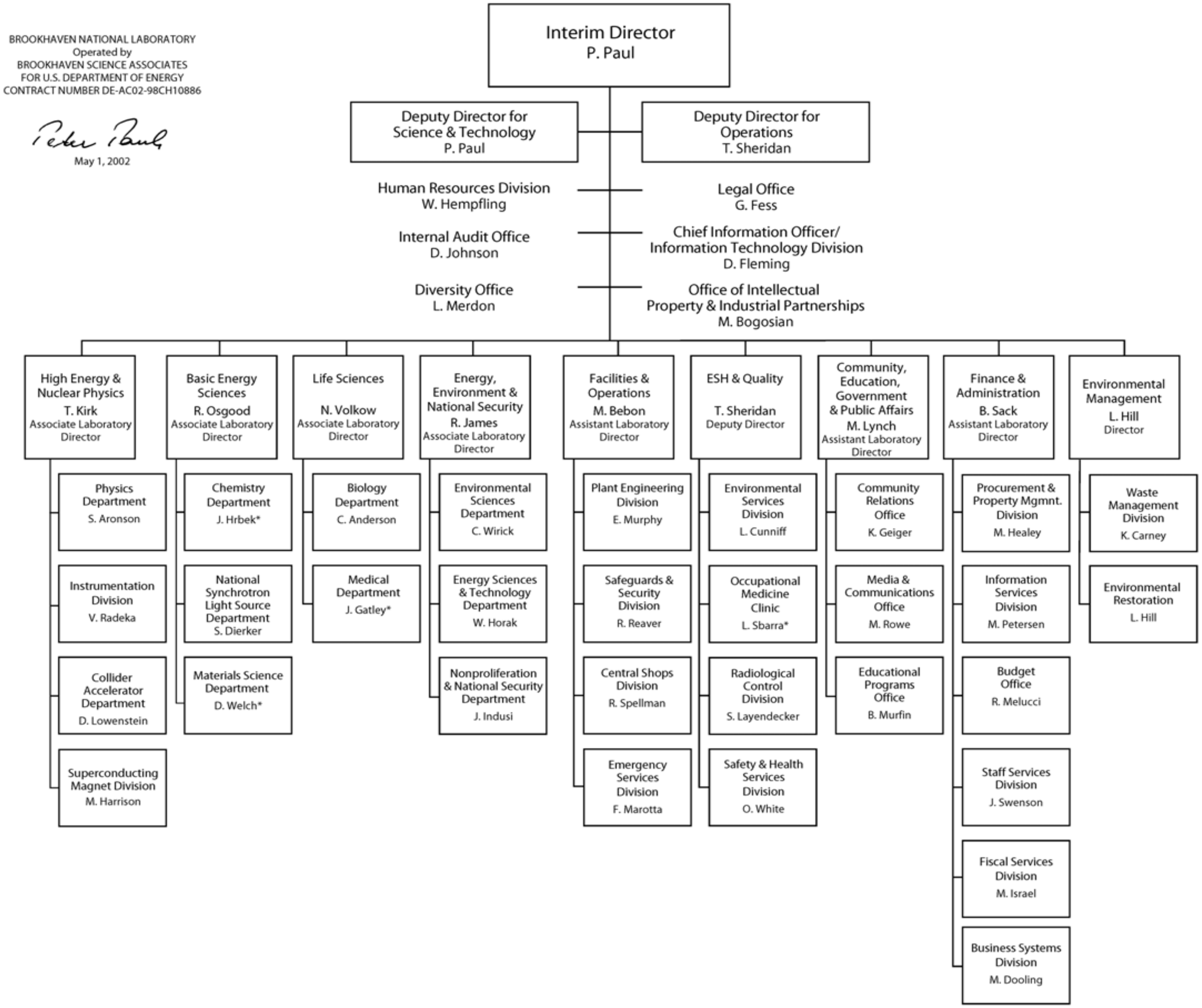

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Brookhaven National Laboratory

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Brookhaven National Laboratory

Executive Summary

This document presents the vision for Brookhaven National Laboratory (BNL) for the next five years, and a roadmap for implementing that vision. Brookhaven is a multidisciplinary science-based laboratory operated for the U.S. Department of Energy (DOE), supported primarily by programs sponsored by the DOE's Office of Science. As the third-largest funding agency for science in the U.S., one of the DOE's goals is "…to advance basic research and the instruments of science that are the foundations for DOE's applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world, and the nature of matter and energy" (DOE Office of Science Strategic Plan, 2000 http://www.osti.gov/portfolio/science.htm). BNL shapes its vision according to this plan.

This Institutional Plan describes what Brookhaven is today and where it will be in the future.

Today -

Brookhaven National Laboratory is first and foremost about cutting edge science and the technological advances that flow from it. More than 600 of its ~3000 staff members are Ph.Ds. BNL executes world-class programs in High Energy and Nuclear Physics, in Condensed Matter Physics, in Chemical and Materials Sciences, in Plant, Structural, and Environmental Biology, in Nuclear Medicine and PET and MRI imaging, and in Energy and Environmental Sciences. The Laboratory also contributes significantly to the DOE's applied missions in Energy Resources, Environmental Quality, and National Security. In all these endeavors, BNL strives to have programs that are among the best worldwide.

Brookhaven is about Instrumentation and Facilities. BNL builds its experimental and computational research around novel and forefront instrumentation that most often is developed by, and built at, Brookhaven. The Laboratory supports one of the top instrumentation divisions in the US. Throughout its history BNL has developed leading accelerator concepts, novel research reactor designs, and a diverse array of advanced instrumentation. Just within the last year, BNL began full operation the Relativistic Heavy Ion Collider. This facility has two major missions: the search for, and exploration of, the quark gluon plasma, using collisions of 100 MeV/A gold nuclei, and the exploration of the spin of the proton, using collisions of spin-polarized 250 GeV protons. The Alternating Gradient Synchrotron (AGS) serves as the injector to RHIC while still delivering the world's most intense proton beams for high quality, high energy and nuclear physics research and for space radiation research sponsored by NASA.

For Basic Energy Sciences (Chemistry, Material Sciences, and Condensed Matter Physics) and increasingly for Biology and Medicine the Laboratory operates the National Synchrotron Light Source (NSLS), which serves approximately 70 beam stations on two rings with electromagnetic radiation from the infrared through the ultraviolet to the x-ray spectrum. This facility provides beams for research for over 5,500 hours per year. A Deep Ultraviolet Free Electron Laser (DUV-FEL), working on the advanced principle of laser seeding and High-Gain Harmonic Generation (HGHG), is close to completion. The Laser-Electron Accelerator Facility provides short-pulsed electron beams for chemical studies, and several transmission microscopes serve the materials research community. After the shutdown of the High Flux Beam Reactor, BNL's neutron scientists set up instruments at the National Institute of Standards and Technology (NIST) and High Flux Isotope Reactor (HFIR) and are preparing instruments for the new Spallation Neutron Source at Oak Ridge.

In the Life sciences, BNL researchers use the NSLS x-ray beam lines for structural biology, advanced Positron Emission Tomography (PET) cameras, 4 Telsa whole-body Magnetic Resonance Imaging (MRI), and 9 Tesla animal MRI for neurological, medical and behavioral research.

Brookhaven National Laboratory

BNL is about users. The Laboratory hosts over 4,000 users annually, with RHIC (~1100 users) and the NSLS (~2,500 users) being the main user centers. During the year there can be over 150 graduate students from the Nation's leading research universities performing their thesis research at the Laboratory. Brookhaven's extensive user support systems focus on making the users stay at BNL as productive and enjoyable as possible.

BNL is about the Community: An extensive outreach program takes the story of our mission and our work to the community, both locally and regionally. A Citizen's Advisory Council and the Brookhaven Executive Round Table bring local citizen groups and officials to the Laboratory. The BNL website (http://www.bnl.gov/bnlweb/newsindex.html) informs the world around us about recent discoveries, advances, and developments at BNL. A summer program opens the Laboratory to more than 5000 summer visitors and explains all our programs and capabilities. The BNL Educational Office and the Science Museum serve about 12,000 local school students each year. And, of course, BNL operates all its facilities and performs all its research in strict compliance with all environment, safety, and health regulations. It is the only national laboratory that presently is certified, and recently was re-certified as complying with the ISO-14001 standard for environmental performance.

Tomorrow –

Brookhaven will play an essential role in the emerging science of the nanoscale. The highest priority initiative for the next five years is the start-up of a new Center for Functional Nanomaterials. This new type of user facility will provide advanced fabrication and characterization capabilities at BNL, serving R&D nanoscience endeavors in materials, condensed matter, and chemical sciences at BNL, universities, and industries in the Northeast. The Center will be located directly adjacent to the NSLS offering an unsurpassed synergy and a major step forward for materials research at Brookhaven. This capability also will be crucial for a Catalysis Institute or Center proposed by BNL for research on the chemistry and surface science of catalysis. The NSLS, one of the most productive and most used light sources, is a "second generation" facility. BNL plans to modernize this important user facility and thereby open up new opportunities for scientific discoveries in material science, condensed matter physics, and structural biology. The plans borrow some of the concepts of an energy recovering linac with a design that can smoothly transition from a high-brightness ring facility to an Energy Recovery Linac, if that technology becomes feasible. These developments draw crucially on the synergism at BNL of scientists working at the Accelerator Test Facility, RHIC, and the NSLS.

Brookhaven will continue to provide the world with cutting edge capabilities in Nuclear Physics: In Nuclear Physics, the proton polarization essential for the RHIC Spin program will be improved. Development work will focus on a 40-fold increase in heavy ion luminosity (RHIC II) and concomitant detector developments. This involves electron cooling of the RHIC heavy ion beams at full energy. In the long term, RHIC will evolve into eRHIC with the addition of a ~10-GeV electron ring for e-Au and e-p collisions. To accomplish these ends, RHIC II and eRHIC will be combined in a single line item construction project.

Brookhaven will continue to work with other DOE laboratories to provide new, cutting edge facilities to advance science and to make its facilities available for other agency-sponsored research. BNL and other sister laboratories have and will continue to engage in interlaboratory R&D for designing and developing new facilities, such as the Spallation Neutron Source, as well as team research endeavors with and at other Laboratories, such as Fermi, TJNF, LBNL, ANL, and ORNL.

The High-Energy Physics program proposes to begin construction of the detectors for measuring sensitive Rare Symmetry Violating Processes (RSVP), a program that the NSF would sponsor. These experiments will use the intense proton beams of the AGS. In FY03 the Booster Application Facility

(BAF), under construction for NASA, will be completed and radiation biology research will begin. The BAF uses the heavy ion beams from the Booster ring of the RHIC–AGS complex to simulate space radiation effects encountered by astronauts.

Brookhaven will continue to focus and expand its role in Life Sciences for both the Department of Energy and for other key federal agencies: Brookhaven will focus it talents and capabilities in biological sciences in developing and executing its program in microbial communities and their use for environmental clean up and Carbon Management as part of DOE's Genome to Life Initiative. This is a crucial step in the further alignment of BNL with the DOE's priorities in biological sciences. BNL also is aggressively building up its capability in cryo-electron microscopy and a program on complex proteins (such as membranes), which are decisive for the interaction between cell and environment.

NIH will continue to sponsor beamline upgrades and research at the NSLS as well as in our research departments. This year BNL significantly improved user services at the NSLS, thanks to grants from NIH and funds from the DOE OBER.

Further advances in medical imaging will draw on plans to acquire a 7 Tesla whole-body MRI to study drug addiction. The lack of a broad and efficient production facility for medical research isotopes has hampered research in medical isotopes at BNL and nationwide. Brookhaven is advancing the Cyclotron Isotope Research Facility (CIRC), a high current 70-MeV cyclotron, to provide the capability for the production of, and research on, the next generation radiopharmaceuticals, as well as to train the next generation of radiochemists.

Brookhaven will continue its preeminent role in expanding our understanding of global change: BNL researchers will continue to focus on understanding atmospheric chemistry, as well the creation and evolution of aerosols and their effect in global heat balance. As part of a Carbon Cycle Initiative, we will extend the knowledge of carbon sequestration in vegetation gained through the FACE (locally enriched CO_2) program into multivariate techniques, including temperature and hydrological cycle soil moisture. A model of the future terrestrial ecosystem research facility is being developed in partnership with ORNL.

Brookhaven will expand its contribution to the national effort in Counterterrorism: The events of September 11th became a turning point in Brookhaven's counterterrorism and nonproliferation programs. BNL is a focal point for a steady flow of inquiries from citizens and government leaders about how to enhance the long-term security of the region. Historically, Brookhaven has, and continues to, develop advanced sensor technologies and risk methodologies to detect and identify nuclear, chemical and biological threats with greater sensitivity and specificity, as well as offer greater assistance to Russian facilities to help in safeguarding their stored nuclear materials. Now, the Laboratory is leading efforts to assemble critical partnerships with technology leaders in New York, and emergency responders within metropolitan New York City, to understand their needs and rapidly deploy suitable instrumentation to meet them. Research and development will grow in the areas of non-intrusive inspection technologies for standoff detection of nuclear weapons, dirty bombs, toxic chemicals, biological pathogens, and explosives.

Brookhaven will become a 21st century facility for R&D, providing modern space for employees and users: The Laboratory's infrastructure, which, in some instances, dates back to the first and second World Wars, will markedly improve over the next few years. Old barracks are being demolished rapidly. In their place, construction will begin in FY 03 on the first building of BNL's Master Plan, the Research Support Center. The Energy Science Building and User Science Buildings are planned for the following years. Finally, to provide adequate quality on-site apartment housing for the still growing user community, the Laboratory is rapidly exploring plans for an apartment complex on-site built by private developers. Such housing could be available as early as 2004. These plans will go a long way to move BNL's infrastructure and user support facilities into the 21^{st} century.

1.0 Introduction

Brookhaven National Laboratory (http://www.bnl.gov/), a large research institution on Long Island, New York, is operated by Brookhaven Science Associates (BSA) under contract with the U.S. Department of Energy. With about 3000 employees and an annual budget of more than $450 million, the Laboratory is one of the largest employers in Eastern Long Island. Its 350 buildings occupy almost 5,300-acres on the western edge of Suffolk County's environmentally important Pine Barrens.

Since its founding in 1947, the Laboratory's primary mission has been scientific research in fields requiring unique, complex and often large facilities, and in the design, construction, and operation of those facilities for external users as well as for its own scientists. BNL’s research departments consist of four directorates (Nuclear and High-Energy Physics, Basic Energy Sciences, Life Sciences, and Energy/Environment/National Security). Other departments are devoted to future and ongoing scientific facilities. The largest of these facilities are particle accelerators and synchrotron light sources. More than 4000 scientists from the United States and abroad come to the Laboratory each year to use BNL's facilities and to participate in joint scientific ventures with its staff.

The following recent successes highlight work performed at the Laboratory in the past year.

Scientific Breakthroughs:

High Energy and Nuclear Physics:

- RHIC accelerated beams of polarized protons to the highest energy ever. The polarized spin research program is the first-ever experiment where the protons in two colliding beams all are spinning in a controlled direction.
- Physicists from Canada, the U.K., and the United States announced the first results from the Sudbury Neutrino Observatory (SNO) and provided a solution to a 30-year old mystery, the puzzle of the missing solar neutrinos. The solution lies not with the Sun, but with the neutrinos, which change as they travel from the core of the Sun to the Earth.
- BNL’s physicists produced a significant number of "doubly strange nuclei," or nuclei containing two strange quarks. Studies of these nuclei will help scientists explore the forces between nuclear particles, particularly within strange matter, and may contribute to a better understanding of neutron stars, the super dense remains of burnt-out stars, which are thought to contain large quantities of strange quarks.
- After careful study of six trillion subatomic particle decays, an international collaboration of physicists announced that they have spotted one of the most rare occurrences in the subatomic world — for the second time. The collaboration, called "E787,” reported the first-ever example of this rare decay four years ago. The second observation represents an important confirmation of that discovery.
- BNL’s scientists, in collaboration with researchers from eleven institutions in the United States, Russia, Japan, and Germany, announced their latest result from a groundbreaking experiment dubbed muon g-2, a precision measurement of the anomalous magnetic moment of the muon, a type of subatomic particle.

Basic Energy Sciences:

- Scientists at BNL developed a novel imaging method, known, as “ion pair imaging spectroscopy,” that will help them understand better the excited state properties of previously hard-to-study molecules. The technique will use crossed beams of light and molecules
- U.S. Patent No. 6,179,897 was granted to BNL scientists for a novel way of making metal oxides. This class of compounds, which includes magnesium oxide and zinc oxide is commonly used in

catalysts, and is important to the growing field of nanotechnology. The new method avoids some of the problems of traditional methods, "and allows greater control of the particle size and chemical composition of the product."

- Scientists at BNL found a way to make a plant enzyme that is 100 times more efficient than similar enzymes found in nature. The research offers insight into how enzymes evolve, and may one day lead to methods to boost production of other useful plant products.
- BNL and DuPont's Central Research and Development Department in Wilmington, Delaware, developed a new class of catalysts that could someday convert plant-derived feedstocks, or raw materials, into industrially useful materials, such as chemicals and synthetic fibers.
- BNL scientists developed a new metal alloy that could greatly improve the performance of rechargeable batteries for portable electronic devices and electric and hybrid electric cars.
- X-ray diffraction was used to find a new crystal phase of many piezoelectrics. This phase gives these crystals their strong response.
- BNL's scientists working in an international collaboration with the School of Chemical Sciences at England's University of Birmingham have discovered some materials that expand under pressure. These unusual materials may have applications as "molecular sponges" for soaking up chemical pollutants or even radioactive waste.
- Using crystallography, scientists elucidated the molecular structure of two cancer-related proteins binding to one another, identifying the molecules' biochemical, and signaling properties. The three-dimensional structure of the cancer-related molecular complex was determined at the NSLS. This is the first detailed picture of the proteins interacting with each other, indicating which areas are essential for the development of cancer. The characterization of their structure may be used eventually to design novel drugs that interfere with the normal function of these proteins and prevent cancer growth. The work results from a scientific collaboration led by Memorial Sloan-Kettering Cancer Center.
- BNL physicists provided new insight into why some materials made of stacks of metallic planes act as conductors in the direction of the planes, but as insulators in the direction perpendicular to the planes. Scientists suspected that the dual conducting-insulating property is due to electrons interacting so strongly with each other that they do not move individually, but collectively, to carry the current within the planes. There is no previous evidence of such interactions.
- Scientists from BNL and Oslo University offered new understanding of the superconductivity of magnesium diboride (MgB_2), an unusual superconductor discovered only last year. Knowledge about the origin of superconductivity, the ability of some materials to conduct electricity without losing energy, will help scientists improve magnetic resonance imaging (MRI), and the efficiency of electric power transmission, and build smaller, more powerful electronic devices.
- BNL scientists are the first to have created a material with a gradient of gold nanoparticles on a silica-covered silicon surface using a molecular template. The material offers the first evidence that nanoparticles, each about one thousand times smaller than the diameter of a human hair, can form a gradient of decreasing concentration along a surface.
- Understanding the properties of nanoscale materials may allow scientists to manipulate them to produce new nanomagnets, nanocatalysts, and composites with better optical properties. Scientists from BNL and Michigan State University demonstrated a technique that allows them to decipher such fine-level nanostructures.
- Scientists from Arizona University, BNL, and the Smithsonian Institution used carbon-dating technology to determine the age of a controversial parchment that might be the first-ever map of

North America. They conclude that the so-called "Vinland Map" dates from approximately 1434 A.D., or nearly 60 years before Christopher Columbus set foot in the West Indies.

- For nearly 200 years, scientists have known that the elements molybdenum and oxygen can form various large molecules that usually impart a unique blue color to aqueous solutions; only recently were they able to isolate these molecules. Now, BNL physicists have explained their supramolecular structure in solution, as a unique "blackberry" structure, which may represent a new, stable solute state never seen before.
- For the first time, scientists observed the molecular details of biological cells fusing together, a fleeting event never before seen at this scale. This research, which could lead to more efficient drug delivery processes and gene therapy techniques, was performed at the NSLS and Rice University.
- Using nanoscale materials, BNL's researchers developed a method to make more efficient, durable electrodes for use in rechargeable lithium ion batteries and other electronic devices.
- Scientists from BNL and the Norwegian University of Science and Technology used computer modeling to investigate how proteins in yeast cells interact with each other. The modeling program can be applied to interactions in other networks, such as food webs in ecosystems, neutral networks, and the Internet.

Life Sciences:

- As part of an ongoing effort to understand how viruses infect cells, scientists at BNL deciphered the molecular-level interaction between coxsackie virus, which infects the heart, brain, pancreas, and other organs, and the human cell protein to which it attaches. This work may lead to improved ways to thwart viral infections, and may help scientists design virus-based vehicles for gene therapy.
- Scientists at BNL showed that increasing the level of a brain protein important for transmitting pleasure signals can turn rats that prefer alcohol into light drinkers, and those with no preference into near teetotalers. Researchers hypothesize that increasing the level of D2 receptors might decrease alcohol intake.
- An experimental form of radiation therapy, known as microbeam radiation therapy (MRT), now under development at BNL, appears to be less damaging to healthy brain tissue than traditional radiation therapy.
- A new brain-imaging study revealed that, compared with people who do not use drugs, people whom abuse methamphetamine have fewer receptors for dopamine, a brain chemical associated with feelings of reward and pleasure. Furthermore, in the drug abusers, low dopamine receptor levels were linked to reduced metabolic activity in a brain region that regulates motivation and "drive."
- Nicotine is widely believed to trigger dependence by elevating certain brain chemicals associated with pleasure and reward. A BNL study in rats shows that topiramate, a new anticonvulsant drug sold under the brand name Topamax®, currently used treating epilepsy, can block some of the nicotine-triggered changes in brain chemistry, and may have potential for the treatment of nicotine addiction in humans.
- A new brain-imaging study offers insight into why individual patients respond differently to standard doses of Ritalin, a drug used to treat millions of children with Attention Deficit Hyperactivity Disorder (ADHD) each year. Scientist say that this new study suggests the variation may be due, at least in part, to individual variation in the release of dopamine.
- The idea that obese people eat too much because they find food more palatable than do lean people gained support from a new brain-imaging study at BNL. It reveals that the parts of the brain responsible for sensation in the mouth, lips, and tongue are more active in obese people than in normal-weight control subjects.

- A new brain imaging study conducted at BNL indicates that some of the damage caused by methamphetamine can be reversed by prolonged abstinence from the drug.
- Three new enzyme studies undertaken performed at BNL yielded a new strategy for blocking infection by human adenovirus. The findings already have been used to design novel antiviral drugs.
- Scientists at BNL produced the first images showing what parts of the brain and body are most affected by inhaling toluene, a commonly abused solvent found in paints, glues, and other household products.

Energy/Environment/National Security:

- Brookhaven Laboratory licensed its Mercury-Waste Treatment Technology to an affiliate of the largest gold producer in North America. Brookhaven's technology chemically stabilizes and solidifies liquid elemental mercury, a byproduct of gold mining, to safely isolate the material from the environment.
- Pushing the concept of “survival of the fittest” to the extreme, scientists developed strains of bacteria able to live in harsh environments while “eating” carbon-rich materials, such as coal. The bacteria’s digestive action removes potentially harmful pollutants, and could be used to yield more-efficient, cleaner-burning coal.
- Scientists at BNL and Purdue University combined satellite measurements of cloud brightness, water content, and other variables with model calculations of atmospheric aerosols to demonstrate the brightening effect that should be accounted for in assessing the magnitude of global climate change.
- Brookhaven National Laboratory, in collaboration with Caithness Operating Company of Reno, Nevada, won a 2001 R&D 100 Award for developing a technology to recover commercial-quality silica from geothermal brine, a byproduct of geothermal energy production. Retrieving this valuable product from brine, which is generally disposed of as waste, results in cheaper energy.
- An electron-beam welding technique developed at BNL is one of thirteen energy-saving projects nationwide that won a grant from the DOE’s National Industrial Competitiveness through Energy, Environment and Economics program, known as NICE3. The grants help U.S. companies overcome regulatory, economic, and other barriers by demonstrating and commercializing innovative, energy-saving technologies.
- Using data from one of the most comprehensive U.S. air pollution studies ever conducted, BNL scientists identified specific volatile organic compounds as key sources of excessive ozone smog in industrial areas of Houston, Texas. These compounds appear to differ from the traditional sources of ozone pollution in typical urban areas around the country.

<u>*Scientific Awards:*</u>

During the past year, several BNL scientists were recognized for their world-class capabilities and groundbreaking successes, and the Laboratory received awards for its forward thinking programs. The following is a brief summary.

- President George W. Bush named fifteen recipients of the National Medal of Science, the nation’s highest award for lifetime achievement in fields of scientific research. Among the awardees is chemist Raymond Davis Jr. Davis was the first scientist to detect solar neutrinos, the signature of nuclear fusion reactions occurring in the core of the sun.
- Richard Setlow, a senior biophysicist at Brookhaven National Laboratory, has been named the recipient of the 2002 Environmental Mutagen Society (EMS) Award. He is being recognized for his research contributions to the field of environmental mutagenesis.
- Victor Emery, a physicist at the U.S. Department of Energy's Brookhaven National Laboratory was

elected to the American Academy of Arts & Sciences (AAAS).

- Robert Pisarski, Samuel Aronson, and Serban Protopopescu were named Fellows of the American Physical Society (APS). APS Fellowship is limited to no more than one half of one percent of its membership, and election for this honor indicates recognition by scientific peers for outstanding contributions to physics.
- Charles B. Meinhold was awarded the Sklodowska-Curie medal for his outstanding contribution to developing radiation protection standards
- Ralph James, Associate Laboratory Director for Energy, Environment & National Security, was named a Fellow of The Institute of Electrical and Electronics Engineers (IEEE).
- Nicholas Samios was the 2001 recipient of the prestigious Bruno Pontecorvo Prize awarded by the Joint Institute for Nuclear Research (JINR) in Dubna, Moscow. The award recognizes Samios for his contributions both as a researcher in elementary particle physics, particularly neutrino physics, and as a scientific administrator.
- Garman Harbottle, a senior chemist at the BNL, received the 2002 Archaeological Institute of America’s Pomerance Award for Scientific Contributions to Archaeology. The award is one of the two highest honors the Institute confers.
- Vasilis Fthenakis, a senior research chemical engineer at Brookhaven National Laboratory, was elected a Fellow of the American Institute of Chemical Engineers in “recognition and appreciation of superior attainments, valuable contributions, and service to Chemical Engineering.”
- Doon Gibbs, Deputy Chair of the Physics Department, was awarded the distinction of Fellow by the American Association for the Advancement of Science (AAAS).
- James Reilly, a retired chemist who continues to participate in groundbreaking research at BNL, was awarded a 2002 Design & Engineering Award by Popular Mechanics magazine.
- William Marciano, a theoretical physicist, shared in the J. J. Sakurai Prize for Theoretical Particle Physics for 2002 for "pioneering work" on calculations necessary for testing the consistency of the Standard Model, the physics theory that seeks to explain interactions between all known particles. Marciano shares the prize, awarded by the American Physical Society (APS), with Alberto Sirlin of New York University.
- Boris Podobedov from BNL won the American Physical Society 2002 Dissertation Award in Beam Physics.
- Louis DiMauro, a senior chemist BNL, was named a Fellow of the Optical Society of America (OSA). Fellowship is an honor bestowed on OSA members for outstanding achievements in their field.
- Joanna Fowler, a senior chemist BNL, won the American Chemical Society’s (ACS) 2002 Glenn T. Seaborg Award for Nuclear Chemistry. The award honors Fowler “for her pioneering contributions to Positron Emission Tomography (PET), including the development of fluorine-18-fluorodeoxyglucose (FDG), a radiotracer used worldwide for measuring brain function and for diagnosing cancer; and for the development of tracers to study monoamine oxidase.”
- Paul Kalb, a research engineer in the Department of Environmental Sciences was one of seven Long Islanders honored as “Inventor of the Year” by Long Island Business News. He won the honor for inventing a technology that makes the disposal of mercury more practical and safe than existing methods.

Brookhaven National Laboratory

Accolades for Brookhaven National Laboratory:

- Brookhaven National Laboratory achieved ISO 14001 registration for the entire site, becoming the first national laboratory to obtain third-party registration to this globally recognized environmental standard.
- Reflecting its strong commitment to reducing waste and protecting the environment, the U.S. Department of Energy recognized Brookhaven National Laboratory for its expanding pollution prevention program, winning two prestigious awards for projects entitled "Process Evaluation Project" and "Environmental Management System Principles Leading Change."
- After conducting a rigorous third-party review, an independent auditor renewed BNL’s ISO 14001 registration confirming the high quality of the Laboratory’s environmental management system.

2.0 Director's Message

This has been an exciting year for Brookhaven National Laboratory. The most outstanding achievements were the rapid and successful operation of RHIC and the impressive production of science (twenty-seven Physics Review Publications) in just one year. The recently authorized initiative, the Center for Functional Nanomaterials, is another exciting achievement. The realization of the Center is a result of the combined efforts of scientists from Chemistry, Materials Science, and Physics, and the National Synchrotron Light Source (NSLS) and draws strength from its close association with the capabilities of the NSLS. The most noteworthy personal achievement is the award of the National Medal of Science to Ray Davis (retired Senior Chemist at BNL) for his seminal work on the detection of solar neutrinos. Davis' early work demonstrated there was a deficit in the expected number of solar neutrinos and just this year researchers, including scientists from BNL, used the results from the SNO detector to solve this puzzle in a most exciting way.

At the same time that excellent science has thrived, the Laboratory successfully accomplished the very difficult task of effecting a culture change. This transformation is underlined by the fact that BNL was certified and recently re-certified under the ISO-14001 Environmental Standard, by the successful review by the Office of Human Research Protection (OHRP) and by other recent reviews. Simultaneously, the Laboratory is reestablishing a relationship with the local and regional community. These advances were achieved under the leadership of Dr. John Marburger, Laboratory Director from March 1998 until October 2001 when he moved to Washington as Director of the Office of Science and Technology Policy in the White House. It is an important challenge to the Laboratory to preserve the new culture. Only then can Brookhaven be completely effective and successful in its mission as a world-class multidisciplinary science laboratory.

Over the past three years, the Laboratory worked hard to bring its programs into full alignment with the strategic goals of the DOE, especially the DOE Office of Science, as well as with the programmatic structure of the Office of Science. This necessitated some difficult changes, most importantly creating a new Materials Science Department in the Basic Energy Science Directorate. To provide more resources to support its many scientific users, the administrative structure of the National Synchrotron Light Source was re-organized. The new Associate Laboratory for Energy, Environment & National Security, Dr. Ralph James, assumed the leadership role in connecting the Laboratory with the other offices of DOE not encompassed by the Office of Science; he is spearheading the Laboratory's initiatives in homeland defense. A salutary side effect of these reorganizations is the formation of multiple cross-disciplinary and interdepartmental collaborations that resulted in proposals spanning several departments. Collaborations with other national laboratories, notably Oak Ridge, PNNL, and NREL, also increased markedly.

Maintaining and continuously rejuvenating an excellent scientific staff is a major thrust for Laboratory Management. We are pleased with the results of the Postdoctoral Initiative and the introduction of the Goldhaber fellowships (the latter with BSA funds). The number of postdoctoral researchers has risen to over 120, and several already have moved into the scientific staff. We now have eight Goldhaber Fellows and over 100 applicants responded to the recent solicitation.

The Laboratory is now poised to move forward with focused initiatives in most of its multi-disciplinary core capabilities. These initiatives, as outlined in this Institutional Plan, provide for exciting new scientific opportunities. BNL is a vibrant Laboratory, building on its strengths and using the synergy provided by its broad programs to serve the Nation and the world with forefront science and technology, and leading edge instrumentation and facilities.

Brookhaven National Laboratory

3.0 Laboratory Profile

The four key missions of the Department of Energy are Energy Resources, Science and Technology, Environmental Quality, and National Security. Since its inception more than 50 years ago, Brookhaven National Laboratory has been, and continues to be, a leader in the DOE's mission in Science and Technology while making important contributions to the other missions. BNL engages in extensive collaborations with other laboratories, federal agencies, universities, and industries providing expertise and its facilities for solving scientific and technical challenges at the international, national, and regional level. BNL's continuing success depends on our ability to maintain alignment of our mission, goals, and objectives with those of the DOE.

3.1 Mission

Brookhaven National Laboratory's role for the DOE is to produce excellent science and advanced technology in a safe, environmentally sound manner with the cooperation, support, and appropriate involvement of our scientific and local communities. The fundamental elements of the Laboratory's role in supporting the four DOE strategic missions are the following:

- To conceive, design, construct, and operate complex, leading edge, user-oriented research facilities in response to the needs of the DOE and the international community of users.
- To carry out basic and applied research in long-term, high-risk programs at the frontier of science.
- To develop advanced technologies that address national needs and to transfer them to other organizations and to the commercial sector.
- To disseminate technical knowledge, to educate new generations of scientists and engineers, to maintain technical capabilities in the nation's workforce, and to encourage scientific awareness in the general public.

3.2 Core Competencies

Brookhaven National Laboratory is recognized for making fundamental discoveries about the structure of matter and energy, developing and implementing new accelerator concepts, linking of this knowledge to practical technologies, and transferring those technologies to address society's most challenging problems. The Laboratory's success is based on the high quality of its scientific and technical staff, the facilities and technologies available to staff and users in a broad range of scientific fields, and the integration of research disciplines.

The Laboratory's breadth of expertise provides the basis for its contributions to the DOE's missions. One of our vital roles is to provide extraordinary tools for the worldwide scientific community to pursuit basic science and advance technology developments. To provide cutting edge tools, our core competencies are designing, engineering, and operating accelerators and detectors, and in the technology of superconducting magnets for accelerators. We maintain a world-class core of scientists in the physics of energy and matter, the chemistry and physics of materials and condensed matter, chemical energy sciences, biomedical and imaging sciences, energy and environmental sciences and technologies, and systems analysis and modeling. The basic and applied programs let us lead and support the use of our unique facilities and point the way for developing new cutting edge tools.

These core capabilities support an impressive array of facilities at Brookhaven:

- For High Energy and Nuclear Physics: The Relativistic Heavy Ion Collider (RHIC), Alternating Gradient Synchrotron Complex (AGS), Accelerator Test Facility (ATF), and the Superconducting

Magnet Development and Construction Facility.

- For Physical and Life Sciences: The National Synchrotron Light Source (NSLS), Scanning Transmission Electron Microscope (STEM), Transmission Electron Microscope (TEM), Magnetic Resonance Imager (MRI), Positron Emission Tomography (PET), Laser Electron Accelerator Facility (LEAF), Booster Applications Facility (BAF), and the Clinical Research Center and Animal Facility.
- For Data and Computation: The RHIC Computing Facility (RCF), RIKEN Teraflop Computer, National Nuclear Data Center (NNDC), Center for Data Intensive Computing (CDIC), Visualization Center, and the Atmospheric Radiation Measurement (ARM) External Data Center.
- For Medical Treatment: The Radiation Therapy Facility (RTF).
- For Production: The Brookhaven Linac Isotope Producer (BLIP), Target Processing Laboratory (TLP) for producing radiopharmaceuticals, PET Isotope Production Cyclotrons, and the Tandem Van de Graaff Facility.

3.3 FY 03 R&D Resource Profile

In FY 2003, the Presidential Budget for DOE funding at BNL is ~$380M. BNL also expects an additional $95M in Work For Others (WFO) that includes funding from other DOE laboratories or operations offices, and other federal, state, local, and private entities.

The majority of BNL's support (~71%) is provided by the DOE Office of Science (SC) and supports the operations of our unique user facilities, research programs in high energy and nuclear physics, basic energy sciences, and biomedical and environmental sciences, and selected site operations. BNL also contributes to the DOE's mission in Energy Resources, and National Security. The DOE funds R&D in geothermal energy, natural gas storage systems, practical conductors for electric power systems using high T_c oxides, research on battery materials, and studies on efficient and affordable buildings. We expect ~$57M from the DOE to support work in nuclear nonproliferation. Our role in Environmental Quality is focused primarily on activities to restore the BNL site and more than $30M is expected from the DOE's Office of Environmental Management for the remedial action programs.

BNL contributes significantly to programs at other DOE laboratories, federal agencies, institutions, and industry. The work done for other agencies derives from our unique facilities and core competencies. In FY 03 we are projecting a total income of ~$95M from Work For Others (WFO), which includes almost $46M from other DOE laboratories/operations offices. Two major activities dominate the WFO profile; funding from Oak Ridge National Laboratory to support BNL's participation in the Spallation Neutron Source, and funding from NASA to support construction of the Booster Application Facility. Other significant activities include NIH support for crystallography beamline development and research at the NSLS and support for the Neuroimaging Center, and at the AGS, NASA support to operate the AGS for a NASA program in radiobiology research, as well as NNSA support for a program in proton radiography feasibility testing. BNL also projects receiving a significant amount of funding from NIH for biomedical research and from NASA for radiobiological research in support of manned space missions. The EPA will continue the NY Harbor clean-up project.

The Human Proteome Project is a large-scale, multidisciplinary, cooperative effort involving national laboratories, universities, and industry. Along with several other centers, BNL has been piloting procedures for the cost-effective large-scale determination of protein structures by crystallography. In partnership with Rockefeller University, the Albert Einstein College of Medicine, Cornell Medical School, and Mt. Sinai School of Medicine, BNL recently received an NIH grant to further develop structural genomics technologies and to establish a pilot structure-production center.

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In Energy Resources the Nuclear Regulatory Commission provides more than $7M for work on reactor safety, technical support to the Commission, and support for work on Russian and Ukrainian reactors. The Department of State provides the most support in National Security for the program office on international safeguards.

3.3.1 DOE Science and Technology Mission

The DOE's Office of Science, which funds the Laboratory's Science and Technology programs, defined goals for the Science and Technology mission (http://www.osti.gov/portfolio/). These goals are the basis of BNL's planning and are reflected in the Laboratory's Critical Outcomes.

Consistent with these goals, BNL provides cutting edge "Instruments for the Frontiers of Science," including operations of major user facilities, the experimental stations within those facilities, advanced R&D on new accelerator concepts, participation in several major collaborations, and operation of our Imaging Center. In FY 2003, over $100M will support the operation of and research at the Relativistic Heavy Ion Collider (RHIC), the nation's newest major science facility for nuclear physics.

The National Synchrotron Light Source (NSLS) is one of the DOE's principal synchrotron sources. The user community continues to expand in number and discipline. The Laboratory is committed to enhancing the role of the NSLS as a national resource for materials, chemical, and biological research. The NSLS staff continues to participate in the national R&D program for the next generation of light sources.

The Laboratory's initiatives, RHIC II/eRHIC, Super Neutrino Beam, the BNL Nanocenter, Upgrades to the NSLS, the Laser Seeded Free Electron Laser, Cyclotron Isotope Research Center, and the Center for Structural Biology of Membrane Proteins build on the Laboratory's core competencies for providing these extraordinary tools and capabilities for science. Other initiatives focus new challenges of the 21st century: Nanoscience, Environmental Facilities Initiative, Genomes to Life, and Catalysis. A third set of initiatives, User Center and Energy Sciences Center, will enhance the Laboratory's ability to provide modern, efficient space for its employees and user community.

With the permanent shutdown of the High Flux Beam Reactor, BNL is working with other neutron sources in the U.S. to provide expertise in neutron scattering and instrument development. Neutron scientists at BNL engaged in developing neutron sources and instrumentation for other facilities, such as the Spallation Neutron Source and the High Flux Isotope Reactor. BNL also has proposed a Center for Neutron Science to support the unique capabilities residing at BNL and to lead the development of applications of the SNS to a variety of scientific problems.

A challenge for BNL is to advance computation and simulation as a critical tool in gathering and interpreting complex data streams for scientific discovery. The Laboratory is committed to increasing its role by building up the Center for Data Intensive Computing (CDIC) in collaboration with Stony Brook University. This Center already has an active program of simulations that assist research in the hydrodynamics of muon collider targets, accelerator design, brain imaging, and cancer treatment plans. Eventually this investment will increase BNL's role in the DOE's advanced computation programs. The CDIC received some program funding from the DOE starting in FY 02. In computing, BNL also will receive funds from the Office of Science for a collaborative program with Thomas Jefferson Laboratory, Fermi Laboratory, and five university partners to develop a 20 Tera Flop (peak) Lattice Gauge Center at BNL. Through this program, BNL will host the most powerful facility in the world for the very important new particle and nuclear physics theory field of lattice gauge physics.

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Our R&D portfolio in "Exploring Matter and Energy" includes large high-energy and nuclear physics experimental and theoretical research programs, basic studies in heavy ion research, support for research at the Laser Electron Gamma Source, materials and condensed matter research, structural biology, and genome sequencing and analysis.

Several programs at BNL study the emergence of new phenomena as a function of length in the 1 nanometer to 1000 nanometer range, such as the current carrying capacity of high T_c superconducting tape or the electron transfer crucial to artificial photosynthesis that depends on molecular length. A continuous upgrading of the NSLS beam capabilities and a strong program in neutron science are crucial for this effort that is a national priority. BNL's Nanoscience Initiative builds on these core capabilities and is based on a multi-institutional multidisciplinary collaboration. BNL also will receive ~$1M in FY 03 for designing and engineering a new Nanoscience Center.

BNL's crosscutting biomedical initiatives would expand the DOE's role in biomedical research by supporting the basic tools and facilities needed to advance the current state of knowledge about cancer, aging, substance abuse, and even the effects of space radiation during deep space travel.

The DOE's Office of Science support for the Structural Biology Experimental Research Program was redirected in FY 01. While funding for several projects was terminated, new funding was obtained for projects related to the Characterization of Protein Structures and Complexes, the Analysis of Human Proteins Induced in Response to Ionizing Radiation, and the Operation and Development of the STEM.

The new DOE initiative, Genomes To Life (GTL), provides an exciting focus for the expertise developed over many years in the Biology Department to understand the basic principles of biological interactions both at the molecular level and within ecosystems comprised of microbes and higher forms of life. In response to the initial call for GTL proposals, a group of scientists from BNL, other national laboratories, and academic institutions submitted a joint proposal to develop cutting-edge, high throughput DNA sequencing methods to identify and quantify microbes in the environment, analyze gene expression profiles in microbes and plant roots within soil communities, and track changes in gene expression in response to environmental stimuli such as contamination of soils with radionuclides or heavy metals. The development of these ultrasensitive sequencing methods will allow scientists to monitor microbial species that cannot be propagated as pure cultures in the laboratory and identify coordinately regulated genes that may define novel metabolic pathways responsive to environmental stress. The work also is relevant to the DOE's efforts to develop renewal resources for carbon management.

Subsequent calls for GTL proposals will focus on characterizing interactions that enable proteins to function together as cooperative "molecular machines". The Biology Department's strengths in structural biology and protein expression, and its long experience in characterizing the biochemistry of protein complexes derived from bacterial, plant, and mammalian cells, position the Department for responding to these new directions. The STEM and new CryoEM microscopy facilities are well matched to the GTL's objective of developing methods for imaging protein complexes in living cells or in fixed sectioned cells. Therefore, several areas of Biology Department expertise have excellent prospects to flourish under the GTL program.

Fueling the Future is a "critical goal" for the DOE where the S&T mission includes basic research that will lead to cleaner, safer, more efficient energy systems. In FY 03, the DOE will support basic research that includes thermal-, photo- and radiation-induced reactions in condensed media, structure-function designs of photosynthetic and catalytic porphyrins, and the synthesis and structure of conducting polymers. We are proposing to establish a new Catalysis Institute, a major component of the BNL strategic science planning for the next 10 years. BNL has several initiatives in catalytic science that are important and converge with the plan for this institute. They include a major new program in nanocatalysis, with a scientific focus on understanding the role of dimensional size on catalysis reactivity; a new program to develop a suite of synchrotron beamlines for catalytic science; major scientific research in the areas of electrocatalysis; a strong existing program in heterogeneous catalytic science; and emerging research in computational tools for studying cluster reactivity.

At BNL, basic research in "Efficient Energy Use" includes research on photo-induced molecular dynamics in gas and condensed phases, gas phase molecular dynamics, and catalysis. Our basic research to address the challenge of "Clean and Affordable Power" includes research on superconducting materials, metal-environment interactions, and basic studies of materials by neutron scattering, electron spectroscopy, and powder diffraction.

The DOE also funds R&D to address the challenges of "Protecting the Living Planet". In the biomedical area, this supports research in radiotracer chemistry and neuroimaging, high-field magnetic resonance imaging, and radioisotope production. In FY 02, BNL received new funding for an initiative in Universal Imaging. Our program initiatives in Biomedical Sciences will enhance our capabilities in cellular biology, functional genomics, cancer research, and imaging. Collaborative participation of scientists from BNL's Biology and Medical Departments in the DOE's Genomes to Life initiative is expected to grow over the next five years.

The DOE also supports BNL programs related to defining the "Impacts of Energy Related By-Products on People and the Environment." These funds support R&D in the Chemistry and Microphysics of the Troposphere, the Free Air Carbon Transfer and Storage experiment, participation in the multi-institutional ARM program, and research on aerosols.

A continuing challenge is to strengthen the nation's institutional assets for basic science and multidisciplinary research. In FY 03, the DOE will allocate over $22M in both programmatic and non-programmatic construction to enhance the science facilities and improve the infrastructure at the Brookhaven site. However, the Laboratory is over 50 years old, and needs a significant and sustained increase in infrastructure funds to improve aging facilities and to provide adequate services, utilities, and space for staff and visitors.

3.4 BNL Planning Principles

The Laboratory's planning basis includes the strategic requirements of the Department of Energy, considers input from the scientific community at BNL and at large, and maximizes use of the capabilities of the Laboratory. The Laboratory's internal planning principles include the following:

- We will build on the strengths at the Laboratory in accelerator-based sciences and technologies, detector and imaging technology and research expertise in a broad array of scientific disciplines. We will fully align our missions, goals, objectives, and expectations with those of our customer, the DOE, and other sponsors and stakeholders. We will assure the quality and alignment of our science and technology programs through a robust peer review program.
- BNL will strive to expand its contribution to the DOE's missions in Energy Resources, Environmental Quality, and National Security by leveraging our unique assets in user facilities, instrumentation, and basic science.
- We will form strong partnerships with other laboratories within the DOE system to perform the research needed to address the challenges of the 21st century. We will meet BNL's assigned goals for the Spallation Neutron Source, the Large Hadron Collider, and the ATLAS detector.
- We will strive to increase BNL support from other federal agencies to assure the availability of our

facilities throughout the government.

- We will position BNL as a leader in computational science through the Center for Data Intensive Computing. We will re-engineer BNL's computational and information capabilities to support and enhance our progress in other research areas.
- We will add the critical competencies needed to strengthen our overall strategic position and support the advancement of our programs. We will make the recruitment and retention of high-quality scientific staff a Laboratory priority. We will develop our human resources through training, recruitment, incentives, and a focus on diversity.
- We will strive to transfer needed technologies to industry and contribute to the education of the future generations of scientist and engineers.
- We will plan and implement improvements to our infrastructure, both the management systems and processes, and the physical plant.

4.0 Laboratory Strategic Plan

Science-based multidisciplinary planning at Brookhaven National Laboratory involves strategic choices among a broad range of opportunities. The basic planning units at BNL are the Science and Facility departments. Input for setting priorities starts with the departmental planning committees that advise the department chair and who develop a strategic plan for the department. These plans and the DOE's planning initiatives and priorities form the vision for the four Science and Technology Directorates for their three-year to ten-year planning horizons. These visions are presented as a group at the major Strategic Planning meeting that involves all senior science managers, augmented by selected group leaders from science and technology. The products of this planning meeting are programmatic initiatives (which extend and/or amplify existing programs) and a list of high-priority Laboratory Initiatives that will extend or create new capabilities and/or research directions.

The Laboratory Initiatives presented here are BNL's long-term priorities and centers of internal investment. They are updated every year, but are not expected to change rapidly. The selection of key Laboratory initiatives is based on those innovations where BNL can make substantial contributions to the long-term priorities of the DOE. For example, throughout its 50-year history, BNL scientists have played an innovative role in many scientific areas, but especially in accelerator physics and accelerator-related science. The eRHIC initiative and the Storage Ring Based Light Source initiative are related through a common new technology – high-power, high-brightness electron beams. The VLB Neutrino Beam initiative modestly upgrades BNL's AGS accelerator, already the world's highest-intensity multi-GeV proton synchrotron, to create a world leading neutrino source to exploit the opportunities in particle physics research opening up in neutrino physics.

Both the programmatic initiatives, included in Section 5, and the Laboratory Initiatives are updated and validated at a second planning meeting during the second quarter of the fiscal year. The senior science managers and all the chairs of the departmental planning committees attend it. Some initiatives that have scientific merit but were not supportive of current DOE planning have been replaced. The time scale of the selected initiatives ranges from three years to ten years. *Initiatives are provided for consideration by the Department of Energy. Their inclusion in this plan does not imply the DOE's approval of or intent to implement an initiative.*

4.1 Next Generation RHIC (NP)

The Relativistic Heavy Ion Collider is an international flagship facility for Nuclear Physics and the major new capability in the BNL Nuclear Physics program. RHIC lets scientists explore Quantum Chromodynamics (QCD), the theory of the strong interaction, in the nuclear environment. In the first phase of the program, emphasis is on studying the quark-gluon plasma using relativistic heavy ions, and on spin physics at the quark level using energetic polarized protons. For the next five years, these capabilities will be unique worldwide. In its planning, the Laboratory is responsible for assuring the cutting edge capability of this facility for these two core science programs. Because the planning, R&D, and design phases of any major improvement to RHIC-class facilities typically require years to accomplish, the planning for such upgrades starts as soon as the facility begins operation and continues from then onwards. The first improvement cycle for RHIC will transpire as incremental improvements to the machine and detectors that will provide the capability for significant upgrade to its luminosity. Heavy-ion and spin physics members of the nuclear physics community have been involved with making the physics case for this incremental upgrade as part of the Long Range Plan for Nuclear Physics.

Over a longer time, the Laboratory is initiating plans for a more significant luminosity upgrade and for a new experimental capability in the RHIC complex to address the next scientific frontiers in nuclear physics, among them the production of heavy quarks, quarkonia, highest p_T production spectra, and W production. Introducing electron cooling at full energy for the heavy ion beams and substantial detector upgrades to the STAR and PHENIX detectors will provide an order of magnitude improvement in luminosity so that rare processes can be studied. A new 10 GeV electron beam, brought into collision with one of the existing RHIC beams, and a new experimental detector to view the electron-heavy ion collisions and electron-polarized proton collisions, will allow RHIC to offer exciting possibilities for addressing new QCD physics, such as small-x gluon properties, the possible color gluon condensate and nucleon structure in the nuclear environment. The conceptual new "eRHIC" facility that would enable these advances is in the early planning phase; workshops involving the interested nuclear physics community were held in New Haven and at BNL.

4.1.1 RHIC Luminosity Growth

Because the cross sections for heavy-ion collisions are geometric, the basic collision rates, even for central ion-ion collisions, are large and the initial collider luminosity for RHIC gold ion collisions is modest (2 x $10^{26}cm^{-2}sec^{-1}$) at the collision points. This is because RHIC is the first heavy ion collider in this energy regime, and all the phenomena are of interest to investigate and measure. The initial research program began in FY 2000 with the four original RHIC detectors, BRAHMS, PHENIX, PHOBOS, and STAR. Full design energy (100GeV/nucleon beam) was achieved in the spring of 2001 and full initial gold on gold luminosity was achieved later in that run. Commissioning of polarized proton beams at 100 GeV per beam was started in early 2002, followed by a short physics run with polarized beams, when the proton-proton elastic scattering experiment took data for the first time. The average beam polarization fell short of the design value, but steps were initiated to bring the polarization to design values in the next two years.

Over the next few years, we will realize important improvements beyond the initial design in the machine and detectors, setting the stage for the further luminosity upgrade included in the major eRHIC construction project discussed in the next section. As part of the near-term programmatic upgrades, the operational reliability and collider beams' diversity will be improved by introducing the new Electron Beam Ionization Source (EBIS). This new ion source will enable collisions of heavy ion beams, up to, and including uranium. The RHIC experimental detectors also will realize incremental improvements in their capabilities.

The scientific motivation for increased luminosity is to assure continuing scientific productivity and discoveries and to pursue research results on rare processes that require more data. To do this, the detectors must be improved in step with the accelerators. In the case of the first generation RHIC detectors, the improvements are of two types, rate capability of electronics, and new instrumental capability. The first type is necessary to handle the increased data rates as the luminosity grows. Relatively modest upgrades are needed for this step and are planned as part of the programmatic improvements. These will transpire using planned capital improvement funds included in the RHIC operations budget.

The second type of improvement changes the detector's capabilities in qualitative ways (such as an introduction of hadron-blind detector, sub-nanosecond resolution time-of-flight, high granularity calorimetry) and enables investigation of new phenomena not accessible with the initial instrumentation. The radical form of the second type of upgrade is an entirely new detector (or detectors). Such improvements may be deemed appropriate after the first round of experiments in the new energy regime of RHIC have been carried out. They would be driven by proposals from the scientific user community. Funding for major new detectors is not included in the programmatic upgrade phase, but appropriate machine and detector R&D will be initiated in FY 2003 to explore the most promising directions in instrumentation for the existing detectors. The R&D work will be carried out in concert with the advice of a BNL Technical Advisory Committee that periodically reviews the detector R&D program.

The cost estimates for programmatic improvement for the accelerator complex are reasonably clear because planning is well advanced and R&D for this stage is mostly complete. To achieve a fourfold increase in integrated luminosity, it is necessary to double the number of bunches in RHIC and decrease beta functions at the intersection points by a factor of two. The hardware for these improvements is present already in RHIC and both of these accelerator changes already were demonstrated in test runs. We are confident that we can achieve a fourfold increase in luminosity without electron beam cooling. In the case of the EBIS, the pertinent R&D was accomplished and proof of principle was established with a successful half-scale model of the electron beam solenoid.

4.1.2 eRHIC

The goals of the eRHIC Initiative are to provide a unique new research capability in the world by providing *collisions between 10 GeV electrons with heavy ions in a RHIC beam* and by delivering a *tenfold increase in the luminosity* of RHIC, along with the necessary improvements to the existing RHIC detectors, to exploit this large luminosity increase. These dramatic improvements in the experimental capability of the RHIC complex will allow nuclear physicists to pursue exciting new research paths opened up by the first-ever collisions of electrons with heavy ions at high energies and by exploring interesting rare heavy-ion collision processes that require large integrated beam luminosities in existing RHIC detectors.

We first discuss the research benefits of *electron-heavy ion collisions*. We note that the RHIC Collider lattice is specially designed to hold a very large number of heavy ions in each bunch. Therefore, when multi-GeV electron beams collide with the circulating heavy ion beam, unique experiments probing QCD in the nuclear medium at normal or even very low nuclear temperatures can be done with unparalleled luminosity and center-of-mass energy reach. In addition to making fundamental measurements on parton distributions and QCD sum rules in semi-inclusive electron-proton collisions, electron-heavy ion collisions offer particular advantages for studying hadronic matter at very high (saturation) parton densities. For example, for the same electron energy, electron-gold collisions at RHIC energies produce about the same parton densities as electron-proton collisions at Large Hadron Collider energies. It is predicted that in the saturation region, gluons will form a "color glass condensate", another form of QCD matter. Many experiments are possible with a specially designed detector that could be installed at the 12 o'clock position of the RHIC ring. The electron-gold and (polarized) electron/proton operation could be implemented such that it would be transparent to the regular RHIC heavy ion program.

As part of the Electron Ion Collider (EIC) collaboration, BNL is exploring the design characteristics of a reference 10 GeV electron beam intersecting in one interaction region of RHIC with 100 GeV/A gold ions, or 250 GeV polarized protons. The electrons would be accelerated and stored in a warm, high intensity ring that intersects with RHIC, or accelerated in a superconducting linear accelerator that intersects directly with the ion bunches. The latter scheme would involve complete recovery of the linac beam energy. It is feasible that luminosities of 5x 10^{30} $cm^{-2}s^{-1}$ could be achieved for electron-Au collisions, and 2x 10^{32} $cm^{-2}s^{-1}$ for electron-proton collisions. Table 1 provides a very preliminary cost estimate for both options; the estimate for the linac option is based on figures from the TESLA project. The scientific merits of this initiative and the timetable for possible implementation were considered during workshops and studies for the Long Range Plan for Nuclear Science. The Laboratory plans to request funds for accelerator R&D for this project.

To realize an order-of-magnitude increase in RHIC heavy ion collision luminosity, electron cooling of the full-energy RHIC ion beams is necessary. Conservatively, a factor of ten is achievable with electron and/or stochastic beam cooling; such cooling should be achievable with vigorous R&D in the programmatic development period discussed above. A tenfold improvement in average luminosity means that a year of data acquisition at the original design luminosity of RHIC (30 weeks at $2x10^{26}$ cm^2sec^{-1}) could be accomplished in less than a week with the combined improvements of eRHIC and the interim incremental measures. Conceptual progress leading up to a serious R&D effort on electron cooling is underway in FY 2003.

The main *heavy ion collisions* elements of eRHIC are expected to become operational about two to three years after the Large Hadron Collider (LHC) begins operating in 2007, with a single experimental detector, ALICE, dedicated to heavy ion physics. The LHC program is expected to develop additional heavy-ion experimental capabilities, given the recent interest by the ATLAS and CMS detector collaborations in pursuing heavy-ion physics together with their base particle physics program using proton-proton collisions. The LHC heavy-ion physics program will complement RHIC's heavy ion mission. The two facilities are in very different energy regimes (100 GeV/amu for RHIC vs. 2.8 TeV/amu for LHC). The RHIC regime is ideal for studying the hadron-plasma phase transition in nuclear matter; the LHC regime will provide data in the very high temperature, pure plasma regime. Furthermore, eRHIC will be the center of a dedicated facility with up to four active detectors, improved capability, more running time per year and staffed by experienced scientists. The two facilities, eRHIC and LHC, will offer very complementary programs in heavy ion physics. The heavy ion scientific objectives will become clarified over the next few years as more RHIC data become available.

Table 1 – Cost Elements for eRHIC Initiative

eRHIC ELEMENTS	($ In Millions)
Electron-heavy ion collisions	
10 GeV electron accelerator & storage ring	200
Detector for e-p/Au collisions	100
Intersection region	15
Heavy-ion luminosity upgrade	
Electron beam cooling at full RHIC energy	34
Detector upgrades for rare processes	60
Total Estimated Direct Costs:	409
EDIA@15%Conting@25%+ProjG&A@13%	255
Total Estimated Costs (w/o escalation)	664

4.2 Very Long Baseline Neutrino Super Beam (KA)

The experimental understanding of neutrino physics escalated strongly during the past few years. Recently, the decades-old experimental puzzles of the solar neutrino flux (too low) and the atmospheric ratio of muon to electron neutrinos (also too low) were reconciled startlingly by the realization that neutrinos are not massless at all, and that, by having a small but finite mass, neutrino wave functions are allowed to oscillate quantum mechanically among their three flavor eigenstates as they propagate in space and time. The basic oscillation properties were beautifully demonstrated in the Japanese Kamiokande and Super Kamiokande experiments, the Canadian SNO experiment, and, very recently, the Japanese Kamland experiment. Other experiments in the U.S. and Europe contributed to the demonstration of neutrino masses and oscillations, so now there is no debate about their existence. What remains to be done is to achieve precise measurements of the experimental parameters governing neutrino oscillations. Five experimental parameters completely describe the mass differences and mixing parameters.

Far from being merely a curiosity of nature, the neutrino oscillations phenomenon is likely to demonstrate CP-violation in a way that may explain the missing “dark mass” in the universe, and the currently purely phenomenological CP-violation in the quark sector. The continuing march towards unifying astrophysics and particle physics could take another big step forward with the experimental determination of the neutrino oscillation parameters. The VLB Neutrino Beam at BNL could play a uniquely powerful role in this program of measurements.

What advantage does BNL bring to such measurements? Basically, it was discovered that the best way to unscramble and measure the neutrino mass and oscillation parameters is to create a very intense, wide-band neutrino beam with neutrino energies from about 1 GeV to 6 GeV, allow this beam to fly through the earth for at least 2000 Km to let the flavor oscillations develop fully, and then measure the flavor spectrum of the beam neutrinos in a Megaton class neutrino detector located deep underground. The neutrino beam energies and the distance scales are set by the new experimental results from the experiments noted previously. Fortuitously, the terrestrial distance scales and few-GeV beams are at the right values to make the necessary measurements; otherwise, it would be almost impossible to measure the neutrino oscillations parameters. Furthermore, the AGS machine is optimum for generating few-GeV beams; however, its beam power will need to be upgraded from 170 kW to 1.0 MW. This upgrade (Table 2), which will raise the neutrino intensity to the “Super Beam” class, is straightforward, with a 1.0 GeV superconducting linac appended to the existing 200 MeV copper linac. Then, the protons can be injected directly into the AGS at high rates, bypassing the Booster accelerator, and the AGS repetition rate can be raised from 0.4 Hz to 2.5 Hz, providing the necessary power. All the needed superconducting RF technology is available as a result of other superconducting RF applications, such as the Spallation Neutron Source at ORNL and the superconducting RF acceleration system at Jefferson Laboratory. R&D is being pursued to optimize the horn focusing system needed for an optimum neutrino beam. This new beam system is quite similar to BNL’s earlier neutrino beams.

Table 2 – Cost Elements for VLB Neutrino Super Beam Initiative

VLB Neutrino Super Beam ELEMENTS	$ In Millions
1.0 GeV superconducting LINAC	99
AGS Upgrades to 1 MW Power on Target	58
Proton Beam, Tgt Sys, Decay Pipe & Beam Dump	27
Shielding, Conventional Constr & Installation	35
Total Estimated Direct Costs:	219
EDIA@15%,Cont.@30%&ProjectG&A@13%	150
Total Estimated Costs (w/o inflation)	369

4.3 Next Generation Light Sources (KC)

Synchrotron radiation research has grown rapidly over the last decade, playing an important role in materials, chemical, life and environmental sciences and technologies. As the quality of synchrotron radiation sources improve, new research techniques become feasible. At the NSLS, we are pursuing two initiatives to develop the next generation source. The first involves a new state of the art 3-4 GeV electron storage ring with a full energy injection system to allow ‘top off’ operation. The storage ring lattice is being designed to be compatible with operation as an Energy Recovery Linac (ERL). ERL’s potentially can provide round electron beams and sub-picosecond pulses. In this way, the facility can provide robust, yet cutting edge technology for its user community as its needs evolve. In the second initiative, the Laser Seeded Free Electron Laser (FEL), we will develop a high peak power, short-wavelength free-electron laser that produces light with excellent temporal and spatial coherence and pulses in the femtosecond regime, pushing ultra-fast science to new frontiers.

4.3.1 New Storage Ring Light Sources (NSLS-II)

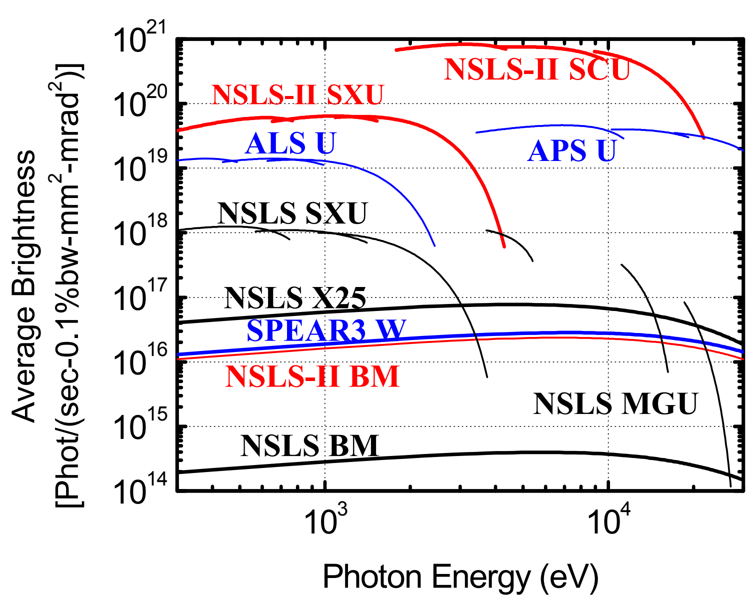
An extensible design is under development to upgrade and modernize the NSLS. It ensures that the new facility will provide cutting edge performance while maintaining the extremely high degree of reliability and beam stability that are the cornerstones of our commitment to users. The NSLS serves a large community of scientific, medical, and industrial R&D activities, and is especially vital for the large research community in the eastern US. A new light source with high-brightness will provide the opportunity for groundbreaking research for US science. With the outstanding track record of the NSLS, the strength of its user community, and its scientific infrastructure, BNL is the ideal place for this source.

The NSLS-II will involve constructing a 3-4GeV electron storage ring with a full energy injector and will be designed to meet the following goals:

- Reduce the horizontal electron beam emittance by nearly two orders of magnitude from 60 nm to 1-2 nm. This advances the state of the art.
- Increase the brightness of the insertion devices by four orders of magnitude to 10^{21} photons/sec/0.1% BW/mm^2/mrad^2 in the 5-20 keV range.
- More than quadruple the insertion device capacity from 5 to 21 devices.
- Provide full tunability of insertion device output in the range of 5-20 keV by developing small gap superconducting insertion devices.
- Incorporate "top off" injection capability to maintain a constant current to better than a 1% fluctuation over several weeks to yield a fixed heat load on the beamline optics.
- Design the storage ring lattice to be compatible with future operation as an ERL.

Figure 1 shows the brightness of the bending magnets and insertion devices in the proposed new ring.

Figure 1 - Brightness of Undulators and Bends in the NSLS-II Storage Ring
This assumes a 3 GeV ring with a stored current of 500 ma. New NSLS-II and current NSLS curves are shown, as well as undulators and wigglers at ALS, APS, and SSRL (SPEAR3) for comparison.



Although the new storage ring envisioned for NSLS-II will allow a subsequent upgrade to an ERL, presently, there are numerous severe technological challenges to realizing an ERL as an x-ray user facility. The need for enhanced source capabilities at NSLS is far too urgent to await the maturity of ERL technology. Our design strategy will ensure that the NSLS continues to push the frontier of new source development, while providing the user community with the brightest and most reliable source of photons well into the 21st century. In particular, the four orders of magnitude increase in brightness provided by the NSLS-II will create many exciting scientific opportunities, such as x-ray imaging with a spatial resolution approaching 10 nm, studying atomic scale dynamics down to sub-microsecond time scale, and structurally characterizing proteins with very large unit cells or those available only as very small crystals. The enhanced spatial and temporal resolutions that can be probed by NSLS-II will be crucial to characterizing the new nanoscale structures fabricated in the CFN.

4.3.2 Laser Seeded Free Electron Laser

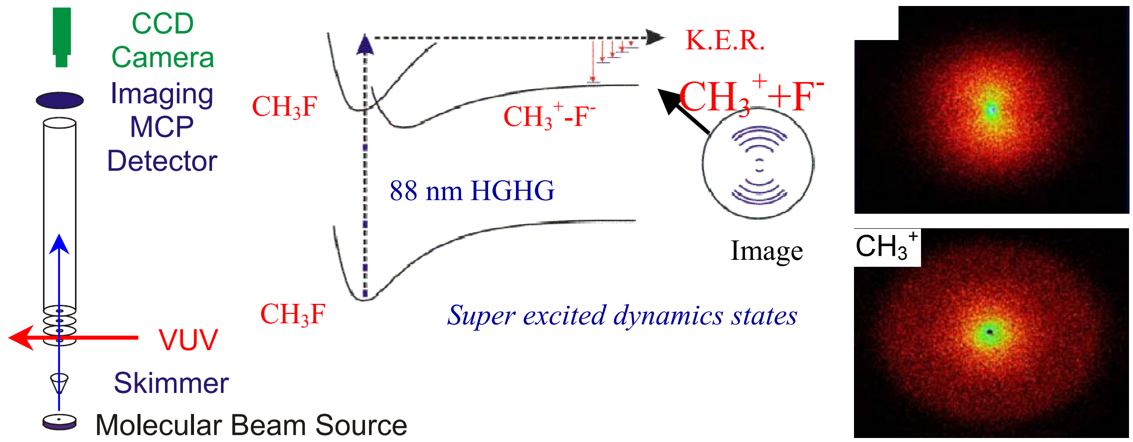
This initiative is a component of BNL's long-range vision to develop next generation sources and science. A unique aspect of the program is developing the High-Gain Harmonic Generation (HGHG) FEL that can deliver excellent temporal coherence and ultra-short femtosecond output pulses through chirped pulse amplification or cascading multiple HGHG stages.

The program uses the Deep Ultra Violet Free Electron Laser (DUV-FEL), a dedicated experiment for developing advanced FEL sources and science. The accelerator consists of a BNL photocathode gun driven by a solid-state laser system scaled from the LEAF gun driver. A four-tank S-band SLAC linac was fitted with an electron bunch compression chicane developed by BNL, in collaboration with LANL and SLAC. The accelerator can provide beam at energies above 200 MeV, with pulses potentially as short as 100 femtoseconds and charge on the order of 1 nC. The 10m long NISUS undulator, used for the FEL experiments, will ultimately range into the deep ultraviolet region (<100 nm). The DUV-FEL offers a flexible yet economical platform for a host of accelerator and applications experiments.

Thus far, we conducted a series of FEL experiments including Self Amplified Spontaneous Emission lasing at 400 nm, direct laser seeding of the electron beam at 266 nm, and HGHG from 800nm laser seed light to 266 nm FEL light. This unique resource allows BNL to probe the limits of sources well ahead of those routinely used today, paving the way for the next generations of synchrotron radiation based research.

A user experimental program also depends on the DUV-FEL's unique light, including the 88 nm third harmonic of the FEL fundamental light. The first user experiments, based on ion imaging techniques developed in the BNL Chemistry department, are examining problems in chemical physics that require higher intensity VUV light than is readily available in laboratory based lasers (Figure 2). To serve the user program, we will further develop the machine for pioneering chemical science experiments.

Figure 2 – Ion Pair Imaging Spectroscopy Experiment at the DUV-FEL
Excitation of CH_3F molecules with the high intensity 88 nm HGHG light produced by the DUV-FEL accesses ion-pair states that dissociate. When one of the products is structureless (such as F^-) the kinetic energy release directly reflects the internal energy in the other product and the dynamics of the process. (Figure 2 is at the top of the next page.)



4.4 Nanoscale Science (KC)

Many of the physical and chemical properties of a material change dramatically as the object reaches a size of about 30 nanometers (nm) in length or less. Similarly, structural or compositional features of similar dimensions often determine the unique properties of certain classes of materials; an excellent example is the pattern of atomic dimensional stripes in many functional metal oxides. These important physical phenomena, along with the emerging technological interest in ultra-small devices, led to a major national and DOE program in nanoscience and technology. Over the last year, BNL is implementing its interdisciplinary plan in nanoscience that is aligned with the DOE's nanoscience goals. The BNL planning involved collaboration among six internal departments or divisions and capitalized on our strengths in chemistry and condensed matter physics. The program also exploits our very diverse synchrotron user facility, the NSLS, as well as our emerging capabilities in advanced, ultrahigh resolution Transmission Electron Microscopy (TEM), and the Laser Electron Accelerator Facility (LEAF) used to uncover charge-transfer dynamics. We are expanding our in-house materials programs and increasing collaborations with our nearby university partners, Columbia, Stony Brook, and Princeton. We have enhanced our capabilities through significant LDRD internal investments and selective new hires. We have been successful in gaining funding for proposals for nanoscale science and have proposals pending additional nanoscience programs and for a related research center (Section 4.10).

The scientific goals of our nanoscience research are to establish an understanding of the chemical and physical responses of *functional nanomaterials* and to develop *new nanoscale materials probes*, particularly involving the NSLS and the high resolution TEM facility. This research will be conducted under the auspices of our proposed Nanocenter. Six scientific thrust areas currently are identified for nanoscience research at BNL; these are discussed below. A new biological thrust area is under consideration:

- *Functional nanoscale strongly correlated oxides.* The work will take a radically new approach in condensed matter physics, working at the nanoscale both to understand bulk behavior and to extend it.
- *Magnetic nanoassemblies.* This work will elucidate, at the most detailed level possible, the physical and chemical factors that control the collective magnetic state in magnetic nanoassemblies.
- *Nanocatalyst materials.* This research will focus on the electronic structure of metal-containing nanoparticles to understand and control their catalytic activity and selectivity.
- *Charge transfer in molecular nanosystems.* The focus of this research is to understand the mechanism of charge transport on the nanoscale and in nanomaterials.
- *Functional thin organic films.* This research addresses the fundamental questions about nanoscale

molecular organization, the relationship between structure and physical properties, and the development of more advanced thin film organics.

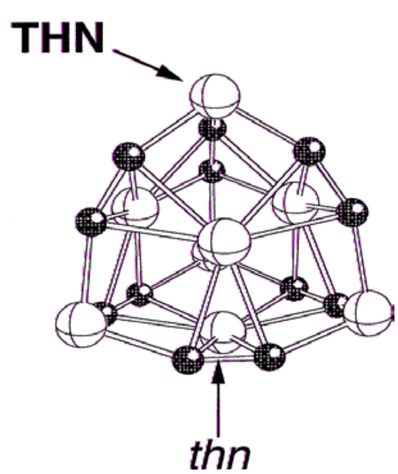
- *Applications in nanoscience.* This research will explore applications of nanoscience to real world problems, such as advanced device development and advanced energy needs.

The Laboratory invested $6 million through FY 2001 and 2002 in a portfolio of internal activities, i.e., Laboratory Directed R&D (LDRD) nanoscience projects and new hires. These investments enabled us to expand the scientific manpower in the area of nanoscience, through hiring postdoctoral fellows and new staff in specific areas, such as nanotube imaging. The LDRD projects include nanomagnetism, charge transfer in molecular materials and catalytic materials. The LDRD research promoted collaborations with various universities and national laboratories in the major thrust areas. Other BNL funds were used to enhance the instrumentation capabilities in nanofabrication and nanomaterials synthesis.

We are participating in, and contributing to, the DOE's program in Nanoscience; proposals were submitted that are aligned with our internal programs and the plan for the BNL Nanocenter. These programs are collaborative with many nearby universities and use our unique facilities and strengths. Two chemistry Nanoscale Science Engineering and Technology (NSET) proposals were funded: Catalytic Nanomaterials, and Charge Transfer at the Nanoscale. Furthermore, three new NSET proposals were submitted recently that addressed magnetic nanoassemblies, metal and alloy nanoparticle electrocatalysts, and nanotemplate directed assembly of soft matter and biomaterials. In addition, the growing program in Transmission Electron Microscopy at BNL received a major boost in support, as did a Materials Synthesis program in the Physics Department. We also have a pending proposal to design and construct a Center for Functional Nanomaterials (see section 4.10).

Our long-term goal is to establish BNL as a regional leader in the fundamental physics, materials science, and chemistry of nanoscience, while building on past successes in bulk functional materials such as piezoelectrics, to change the approach to materials research at BNL, and to forge major and permanent links to the nearby university programs. The BNL Nanocenter will be a focal point and enabler of advanced materials research in the northeast. An example of a new class of nanoscale materials that is under investigation at BNL is shown in Figure 3.

Figure 3 - The M8C12 MetCar Structure
The optimized geometry of the ground state of this cluster was obtained from theoretical calculations. Theory is making important contributions to understanding the properties of this "metallocarbohedrene", a new class of nanometer scale caged-structure materials.



4.5 Catalysis Institute (KC)

This year BNL is developing a plan for a Catalysis Center or Institute that is aligned with the new DOE interest in centers of excellence in catalysis science. Two workshops on catalytic science and synchrotron probes were held at BNL in the last two years. At present, BNL has several initiatives in catalytic science that are central to, and converge with, the plan for this institute, including the following:

- A major new program in nanocatalysis, with a scientific focus on understanding the role of dimensional size on catalysis reactivity.
- A new program to develop a suite of synchrotron beamlines to study catalytic science. This program is being developed in conjunction with several outside catalytic scientists, including Prof. Mike White and Prof. Mark Barteau, from the University of Texas and University of Delaware, respectively.
- Major scientific research in electrocatalysis; developing and using *in-situ* probes using lasers, X-rays, and infrared; and homogenous catalysis.
- A strong existing program in heterogeneous catalytic science.
- The development of a new thrust of scientific research in computational tools for studying cluster reactivity.
- An expansion in the synthesis of nanoscale metal oxide "substrates."

The Institute is a major component of the BNL strategic science planning for the next ten years. Dedicated space will be set aside for the institute, most probably within the Chemistry Department building. GPP funds will be allocated for renovating this space, as needed. We are allocating internal investment funds to attract new scientists with interest in catalytic science to the Laboratory. With these funds, we established important LDRD research and are recruiting young scientists for postdoctoral and assistant scientist positions.

4.6 Cyclotron Isotope Research Center (NE)

BNL is committed to advancing medical radioisotope production and to developing the Cyclotron Isotope Research Center (CIRC), a facility to serve as a reliable year-round domestic source of medical isotopes for nuclear medicine, for R&D, and for education and training. Researchers will use this facility to develop and produce new medical radioisotopes for diagnostic and therapeutic applications, and to develop high-power targets for producing larger quantities of radioisotopes for both Single Photon Computed Tomography (SPECT) and Positron Emission Tomography (PET). CIRC will be available year-round for medical radioisotope research and production and will serve as a much-needed national resource for educating and training future radiochemists and radiopharmaceutical scientists. It will enable the development of new and more effective radiopharmaceuticals for diagnostic PET and SPECT imaging, and also catalyze and advance the relatively new but very promising field of radionuclide therapy for cancer and other diseases.

The centerpiece of the CIRC is a negative ion cyclotron that will deliver protons at energies of up to 70 MeV and continuous beam currents of up to 2 mA. The CIRC will produce an uninterrupted supply of radioisotopes, in sufficient quantity to support research investigations on a national scale, as well as multi-center clinical research with human subjects. Up to four beam lines will provide simultaneous multiple user capability for research, production, and commercial partnering.

The versatility and reliability of this machine combined with its inherent safety and operational flexibility will reposition the U.S. as a premier and meaningful contributor to future clinical research into the diagnosis and treatment of medical conditions, including heart disease and cancer. The missions are consistent with BNL's role as a provider of unique and sophisticated user facilities that serve as research tools to advance scientific knowledge for the benefit of mankind. It will complement other major existing facilities at BNL, such as the AGS, RHIC, NSLS, and BAF. The Conceptual Design Report (CD-0) and an Operations Plan were developed. The latter contains a significant level of detail about this proposed facility. There is strong support for this facility from within and external to the DOE. Further detailed plans will be developed in FY 03.

4.7 Center for Structure of Complex Membrane Proteins (OBER)

Membrane proteins are critical elements of biological processes that are directly related to the DOE’s missions in the environmental consequences of energy generation and use, and human health. Membrane proteins and protein complexes function in microbes as transporters, and in the brain as receptors for neurotransmitters, making them critical targets in carbon management, bioremediation, cell signaling, and human function. Approximately 30% of the genes in a typical bacterium code for membrane proteins; this fraction is larger for eukaryotes. However, as a class, these proteins are difficult to analyze, and therefore, membrane proteins account for less than 1% of known protein structures. To understand how a "Microbial Cell" functions, we need to know how membrane proteins function and to develop new technologies for analyzing the complex structures they form in their native cellular environments.

To attack the difficult problem of understanding the function and structure of protein complexes and membrane proteins, strengths in molecular biology and biochemistry must be brought together in a critical mass with the appropriate analytical tools. This is the Center for the Structure of Complex Proteins (CSCP). The Biology Department has world-renowned expertise in protein expression and protein engineering. This expertise now is coupled with new, high-throughput methods for sample handling to develop and validate approaches and techniques applicable to membrane proteins and complex protein structures. To achieve the critical mass and a fully integrated approach, we are partnering with Stony Brook University to develop a *Center of Excellence* to coordinate the talents and resources of both institutions and to facilitate acquisition of needed resources. Similarly, the expertise from other BNL and Stony Brook departments will add depth to, and broaden, the knowledge base supporting the Center.

The Biology Department hired three new staff to initiate the CSCP. Dr. Dax Fu, a membrane protein biochemist, solved the structure of GlpF, a membrane channel protein that regulates glycerol transport in *Escherichia coli*. He will extend these studies to other bacterial channel proteins and develop basic principles for expressing, purifying, and crystallizing other membrane proteins. Drs. Daniel van der Lelie and Safiyh Taghavi recently joined the Biology Department. They are molecular soil microbiologists with expertise in the analyzing soil communities associated with plant roots and also pioneered the genetic characterization of *Ralstonia metallidurans*, a soil bacterium being developed as an indicator of bioavailability, and as an agent for bioremediation of metal contaminated soils. Metal bioremediation requires a complex of membrane bound transporter proteins.

In FY 02, support from the DOE’s Office of Biological and Environmental Research paid for a 200kV cryo-equipped electron microscope with a field emission gun. This equipment is an essential component of the CSCP for the analysis of two-dimensional arrays of membrane proteins, isolated complex particles, and frozen tissue sections. It will facilitate analyses of membrane protein complexes, including heavy metal antiporters, membrane bound oxido-reductases, and other molecular machines relevant to the DOE’s bioremediation effort. The Cryo-EM complements the STEM facility. Additional funds from the Laboratory funds are being used to recruit an experienced electron microscopist.

More scientists will be added, as resources permit, to provide adequate analytical capabilities for the expression and analysis of complex proteins and protein complexes. A critical component of any modern protein center is mass spectrometry for protein identification and quality control. Additional capabilities in membrane protein biochemistry will be necessary to assure the Center's success.

4.8 Environmental Facilities Initiative (KP)

BNL's Environmental Facilities Initiative focuses on how to effectively use distributed facilities to address specific questions about global change. For example, the DOE funds facilities where researchers can study the effects of enhanced carbon dioxide on terrestrial ecosystems (FACE Facilities), and facilities that measure the flux of carbon dioxide at fixed locations using eddy flux covariance techniques. With the Environmental Facility Initiative, we are developing the capability to couple measurements from FACE and other sites to guarantee that the effects of artificially enhanced carbon dioxide can be compared directly with natural fluxes at the same site. The ability to acquire and manage these large data flows, in near-real time, from widely distributed facilities is crucial to the enterprise's success. We are building specific tools such as research platform software, and developing Internet-based data communications tools to provide real-time control and measurements from widely distributed experimental sites. A growing user community is using them. Since the terrestrial biosphere is the primary driver for the annual variability of atmospheric carbon dioxide, our efforts facilitate the development and use of coupled terrestrial-atmosphere models that can extrapolate today's observations to larger scales and to the hotter, wetter climate that is likely in the next century.

A new type of research capability is needed to enable long-term organized research to be undertaken to understand how terrestrial ecosystems will respond to rapid environmental change. Over the next century, science must provide insightful knowledge of which ecosystems are the most vulnerable and will be the most severely impacted by rapid environmental change, and how ecosystems of the future will look. Designing experiments to address these questions is the grand challenge for ecologists. Brookhaven collaborates with the other national laboratories in developing science plans for manipulating and modeling the research required to answer these difficult questions. Existing ecosystem research facilities do not have the capability to conduct the crucial multi-factor ecosystem experiments. BNL's Environmental Facility Initiative and complementary initiatives at other national laboratories are contributing to the conceptual design of a new distributed facility that can meet these needs. This facility probably will have a long-term mission, of about 10-30 years, a large scale, encompass tens of square kilometers, and have the capability to manipulate CO_2, temperature, water, nutrients, and other parameters.

The DOE's OBER is exploring the possibility of a Terrestrial Ecosystem Research Facility (TERF). In FY 01 and FY 02 BNL participated in efforts to define the concept and develop a plan for such a facility. It will be a test bed of unprecedented scope for monitoring, probing, and understanding how terrestrial ecosystems respond to rapid environmental change and human perturbations. Our overall goal is to provide the DOE with capabilities to help shape the overall focus and roadmap for such a facility or facilities, and to position the Laboratory as a significant partner as the facility and programs are further defined.

4.9 Center for Data Intensive Computing (KJ)

Advanced Scientific Computing is a critical success factor in the DOE's science programs, as was recognized by the creation of the "Scientific Discovery through Advanced Computing (SciDAC)" program. BNL is a leader in one of the SciDAC projects - The Terascale Simulation Tools and Technology Center (TSTT). The TSTT Center is designed to enable application scientists to easily use multiple mesh and discretization strategies within a single simulation on terascale computers. In addition, there is a major national effort to develop techniques that take advantage of the terascale computing platforms currently being acquired. For these programs to be successful, there must bean intellectual atmosphere and culture of scientific computing in which new algorithms and new methods in computer science and applied mathematics are brought to bear on scientific problems. Therefore, Brookhaven established the Center for Data Intensive Computing, directed by the Chair of the Department of Applied Mathematics and Statistics at SUNY Stony Brook. The mission of the Center includes the following:

- parallel and distributed computing and networking,
- modeling and simulation,
- data mining,
- visualization and graphics.

Current efforts are in accelerator science, medical imaging, materials and chemical science, and climate change as well as basic computational science research. The work in accelerator science includes developing parallel codes for particle and spin coupling, and for the study of magnetohydrodynamic effects in targets for the Spallation Neutron Source and a future muon collider. In medical imaging, our efforts include new algorithms for extracting regions of interest from PET scan images of the human brain of normal and addicted subjects, and developing automated systems for the analysis of images of individual neurons.

In materials science we are pursuing first principles calculations on the magnetic response of nanocrystalline wires, on excitation spectra observed in x-ray absorption and transmission electron microscopy, and on the phase diagram of uranium. We are continuing work using quantum Monte Carlo simulation to study finite temperature magnetic properties. We also developed a new parallel code for studying photon localization in semiconductor lasers and contributed to developing algorithms to simulate combustion. In climate change, we developed new parallel codes for aerosol transport in the troposphere. We also are building Galaxy - a cluster of more than 150 Intel processors running Linux.

The aim of the CDIC is to build up a portfolio of programmatically supported research activities, including the addition of up to 10 FTE by 2004 and the purchase of hardware. This Center will enable BNL to fully support the emerging high-priority scientific programs with advanced computing modalities and will assure our competitiveness into the future.

4.10 BNL Center for Functional Nanomaterials (KC)

BNL is planning to establish a DOE Nanoscale Science Research Center ("Nanocenter") whose theme is "tailoring the chemical and physical response of nanoscale functional materials." The Center will enable research in the six scientific thrust areas described in Section 4.4; however, the thrust areas will evolve and change with time, based on scientific results, changing interests, and the DOE's mission.

The Center also houses research on the development of new nanoprobing techniques and instruments. The capabilities of the Center complement those at other national laboratories, such as Argonne and Oak Ridge. A major goal for the Center is to significantly expand our interactions and collaborations with our university partners; this includes more user facilities, the expansion of joint appointments, and the expansion of graduate students working at BNL. Through a preconceptual planning effort, we sharpened the concepts and requirements of the Center's seven laboratory cluster areas and defined an organizational structure for operating the facility and interfacing with the users.

Brookhaven National Laboratory

The BNL Nanocenter, a *Center for Functional Nanomaterials*, will integrate Brookhaven's unique capabilities in a broad range of synchrotron characterization techniques with new capabilities in nanomaterials synthesis and nanofabrication. Our focus of tailoring the chemical and physical response of functional nanomaterials complements those of other planned Centers; it capitalizes on the NSLS leadership in materials probes, and builds on the strengths of BNL's BES programs in strongly correlated electron systems, catalysis, molecular materials, electrochemistry, and nanostructures in complex functional materials. In addition to the Light Source, other major existing facilities at BNL will be used: the 300 kV Transmission Electron Microscope (TEM), the Laser Electron Accelerator Facility (LEAF), ultra-fast lasers and scanning probes.

The centerpiece of the BNL Nanocenter is a new building located contiguous with the existing NSLS facility (Figure 4). The building will house clean rooms, general laboratories, and wet and dry laboratories, as well as office space for BNL staff, university, and industrial users, and space for seminars and conferences. The Center will have seven major laboratory clusters: nanopatterning, proximal probes, electron microscopy, materials synthesis, ultrafast optical sources, and theory and computation. The seventh cluster takes advantage of the capabilities of the NSLS; the Center will have dedicated beamlines at the NSLS, including the soft and hard microprobes, UV soft and spectroscopy, soft and scattering, near field IR, and *in situ* characterization. Instrumentation for these laboratories will be purchased as part of the project.

Figure 4 - Artist's Rendering of the Nanocenter Building
The Nanocenter is to the right of the NSLS.

The BNL Nanocenter will draw researchers from many different disciplines. This is a natural consequence of developing a highly interdisciplinary science program that allows researchers to attack problems from several diverse scientific points of view. Because research will be highly interdisciplinary, the organizational structure will parallel closely that at the NSLS, a large user-oriented facility. A senior scientist will head each of the laboratory clusters with responsibility for the user interface, development of new scientific techniques, and supervision of any user scientific and technical staff in the laboratory complex. Researchers in the six scientific thrust areas of the Center will use these laboratory clusters for their research, each having a different mixture and emphasis. The proposed research and allocation of laboratory and instrument time will be determined by groups of BNL scientists and external users. A Science Advisory Committee will guide the overall science direction. The BNL Center will bring together many organizations within BNL doing materials research including the Chemistry Department, the Materials Science Department, the National Synchrotron Light Source Department, the Condensed Matter Section of the Physics Department, the Biology Department, and the Instrumentation Division. The Center integrates Brookhaven's unique capabilities in a broad range of synchrotron spectroscopies with new material and nanofabrication capabilities. It will be a focal point for collaborations with nearby universities in studies of functional materials at the nanoscale, particularly the State University of New York at Stony Brook, Columbia University, and Princeton University.

The complete design and construction of the Center is expected to take four years with completion anticipated in FY 2006.

4.11 User Research Center (SLI)

RHIC provides the highest energy man-made collisions of heavy ions and the facilities for a worldwide community of researchers to use them in exploring new states of matter at temperatures and densities more extreme than exist now even in the cores of the hottest stars.

In all, some 1,100 scientists presently are involved in the experiments at RHIC, and that number will grow as the facility continues to collect experimental data. Experiments at RHIC use several collider detectors that were designed and built by international collaborations of scientific groups. The four RHIC detectors involve collaborators from some 90 universities and laboratories representing about 20 countries. Hundreds of visiting scientists will be working at RHIC at any given time to coordinate the experiments, operate the detectors, and analyze data, alongside a Brookhaven staff of about 150 dedicated scientists and support personnel. During short periods (e.g., workshops, collaboration meetings) an additional 100 to 200 visitors will be present at Brookhaven for work involving RHIC. It is essential for the success of this important national program that BNL become a vital and effective center, not only for the operation of RHIC and its detectors, but also for the intellectual activity involved in analyzing and understanding the exciting new data that is collected.

Presently, there is not enough space to accommodate such large numbers of visiting users. Moreover, since Brookhaven will be the focal point of a worldwide effort to carry out and analyze these experiments, success requires space where large groups can work together, meet, exchange ideas, and maintain close contact with the experimental equipment. Additionally, proximity to the existing computing facility in Building 515, which is essential for analysis of data, as well as the BNL research staff there, will leverage the investment in this vital research machine. At present, there is no facility that allows this kind of consolidation of the RHIC research.

The User Research Center will provide a permanent facility for the BNL/RHIC scientific staff and the short- and long-term visiting scientific community to carry out the program's mission. Under this project, BNL will construct a new 54,500 square foot office building next to the Physics Department, Building 510. The Center will be located at the core of the BNL site. It will include individual as well as multi-person offices, a large seminar room, two conference areas, transient user space with access to computer terminals for visiting collaborators, and a lobby suitable for public displays and visitor orientation. A center such as this will be a an area where all the research groups can work together, share ideas as well as resources, and engage in the kind of intellectual interchange that is essential to fully exploit a truly world-class accelerator facility.

4.12 Energy Sciences Building (SLI)

Brookhaven National Laboratory is committed to strengthening its programs in applied sciences currently conducted in the Departments of Environmental Sciences, Energy Sciences and Technology, and Nonproliferation and National Security, as well as the Office of Technology Transfer. The Energy Sciences Building Project is a key element in BNL's plan to upgrade and modernize facilities essential to the DOE's missions in applied sciences. With this project, BNL will construct laboratory and office facilities to replace old, outdated, inefficient WW II era facilities that cannot meet mission needs. Executing this project is essential to perform multi-program DOE initiatives in environmental sciences, carbon management, nanotechnology and energy sciences, and to promote industrial collaboration and technology transfer.

The affected departments are currently dispersed among 24 buildings; only two of them are considered suitable for continued use for the applied sciences research programs, even though they are in excess of 40 years old. The Environmental Sciences Department alone is dispersed among 14 buildings where over 65% of the occupied square footage is wood frame structures constructed as temporary barracks during WW II. These buildings were modified into laboratories and offices in the late 1940s, have far outlived their economic life, and are unsuitable for continued use as applied science facilities. The problems associated with these buildings include the following:

- Unsuitable Structural Layout – The buildings originally were small barracks cobbled together to create larger buildings. They cannot be further modified to provide the common areas, conference space, and large laboratory space needed to support the mission.
- Dispersion of Facilities – The existing buildings are dispersed over a wide area of the BNL site. The dispersion of the staff means that scientists are isolated from their peers, discouraging collaboration and negatively impacting productivity and creativity.
- High Maintenance and Operating Cost – The existing wood frame structures are costly to operate and maintain. Wood rot, leaking roofs, sagging floors, structural members not up to current code design, asbestos and lead hazards, old HVAC and electrical systems, old windows, old lighting and poor insulation all require large continued investment just to maintain a minimum functional capability. Energy costs of $1.50/SF are double the amount for a similar sized modern office building.
- Reduced Productivity – The poor existing conditions result in lower worker productivity due to inefficient layouts of office and laboratories. The inability to share resources results in the need for additional supplies, less efficient use of space, and additional support staff that would not be required in a modern, purpose-built facility. The lower reliability of the aged facilities and equipment negatively impacts productive research output and leads to less valid data produced for a given investment. Industry currently expects a 10% productivity increase from their employees after investing in new research facilities.
- Impact on Scientific Staff – The unattractive and unsuitable condition of the existing facilities has made it difficult to retain qualified scientific staff or to attract new staff. While part of the reduction seen in recent years is due to DOE's programmatic realignment, the nearly 50% reduction far exceeds that attributable to program changes. There are many vacant positions that have not been filled due to the competitive disadvantage posed by BNL's facilities.

The proposed Energy Sciences Building will provide approximately 40,000 square feet of laboratory, office, and support space. The two-story structure will be constructed close to the existing applied science buildings 815 and 830, creating an "Applied Sciences Campus" and consolidating staff into 3-4 buildings.

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The facility will include individual offices, two-person offices, state-of-the-art laboratories, and transient user space with access to computer terminals for visiting collaborators, a large seminar room, and conference rooms on each floor. The building will incorporate designs to encourage peer interactions and collaborative visits by staff around the Laboratory; in addition to offices and laboratories, for example, it will house "interaction areas" for informal discussions. This design approach is commonly regarded as the state-of–the–art in research facility design. The building will house capabilities that are used by scientists across disciplines including laser laboratories and two microscopy laboratories. Three general-purpose laboratories and preparation laboratories also will be constructed to accommodate a wide array of research needs. Furthermore, the facility will incorporate sustainable design features that reflect BNL's commitment to implement pollution prevention and energy conservation practices wherever feasible. The laboratory spaces will incorporate concepts being developed as part of the DOE/EPA Labs 21 initiative and U. S. Green Building Council Features to qualify as an LEEDS rated building.

Table 3 summarizes the resource projections for the Laboratory Inititatives.

Table 3 - Resource Projections for Laboratory Initiatives

Resource Projections For Laboratory Initiative (FY 02 $ In Millions)						
	FY 02	**FY 03**	**FY 04**	**FY 05**	**FY 06**	**FY07**
eRHIC[(a)]					0.5	1.0
VLB Neutrino Super Beam[(a)]					1.5	10.0
Laser Seeded FEL[(b) (c)]	0.4	3.2	TBD	TBD	TBD	TBD
NSLS Upgrade [(b) (c)]	0.0	4.0	TBD	TBD	TBD	TBD
70 MeV Cyclotron			9.6	13.0	11.6	2.2
Nanoscience Initiative [(b) (c)]	1.7	2.0	3.1	3.9	4.5	7.0
BNL Nanocenter For Functional Materials [(d)]		1.0	4.5	24.4	40.1	18.6
Catalysis Institute	0	10.0	10.0	10.0	10.0	10.0
Genomes to Life	1.24	2.1	2.13	2.72		
Center for Structural Biology and Membrane Proteins [(b,c)]	1.4	2.2	2.0			
Environmental Facilities Initiative [(b,e)]		TBD	TBD	TBD	TBD	TBD
Data Intensive Computing [(b)]	1.2	2.0	3.0	3.0	3.0	3.0
User Research Facility			1.6	6.8	7.0	
Energy and Environmental Science Building			1.8	7.5	8.6	

[(a)] The resource timetable has not been developed; funds in FY06-FY07 are for planning and development.
[(b)] Funds for FY 01 were provided through the Laboratory Directed Research and Development Program.
[(c)] Funds for FY 02 are provided through the Laboratory Directed Research and Development Program.
[(d)] The Nanocenter proposal was updated for decision in FY03.
[(e)] BNL's role in the out years will be defined as the TERF/EFI concept matures.

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5.0 Department of Energy Programs

Brookhaven National Laboratory has served the large and demanding science community in the Northeastern U.S. with a combination of "big science" facilities and a cluster of basic science departments that ensure the relevance of the facilities to the needs of the scientific community and the missions of the Department of Energy.

Several factors affect the Laboratory's planning:

- The DOE increasingly competes for program funds.
- The needs of users continue to grow.
- In-house research focuses on interdisciplinary activities, and the requirement for advanced computation support will continue to increase.
- The big machines of the future will be confined to the developed core of the site.
- Information technology will increasingly dominate work style.

The vision for the Laboratory is one in which interdisciplinary interaction will be the norm, with a focus on key DOE science priorities where BNL has, and will continue to, demonstrate leadership. We will provide a coherent user experience and quality workplaces for our users and employees, and we will continue to build core capabilities in areas such as advanced computation to further all our research endeavors.

5.1 Science and Technology Facilities

Brookhaven National Laboratory is a multidisciplinary accelerator laboratory with ion/particle acceleration and electron/photon capabilities. The Laboratory has a strong core specialization in accelerator research, advanced magnets, instrumentation, and computation to support our existing facilities and to design and develop new facilities, as well as new applications for existing ones. In the future, BNL will continue as a "center of excellence" for accelerator-based science, including detector, magnet, and computing technologies. The following sections describe our major user facilities and plans for the future. In conjunction with our proposed initiatives, these plans will assure our continued success in meeting the DOE's Science and Technology mission well into the future.

5.1.1 Relativistic Heavy Ion Collider (KB)

Present Program: The Relativistic Heavy Ion Collider (RHIC) is the largest facility for nuclear physics in the U.S. and the most powerful source of heavy ion collisions in the world, creating conditions that occurred microseconds after the "Big Bang". Additionally, RHIC can accelerate, store, and collide polarized proton beams as a result of collaborations with the RIKEN Institute of Japan. RHIC offers the potential for new discoveries about the most fundamental structure of matter. The construction of RHIC was completed in FY 1999; it operated as a national user facility in Nuclear Physics since FY 2000, and achieved full energy gold on gold collisions in FY 2001. The crucial supporting RHIC Computing Facility (RCF) succeeded in its mission to accept the huge flow of data from the detectors, to store and reconstruct it, and to make it accessible for rapid analysis.

RHIC is positioned to discover and explore a form of matter, the quark gluon plasma (QGP) that has not existed in the universe since it was created in the "Big Bang" about 12 billion years ago. With the successful commissioning of polarized proton beams in FY 2002, RHIC will allow the exploration of spin physics at high energies.

The core of the RHIC experimental program includes the following:

- The experimental discovery of the quark gluon plasma and the exploration of its properties, and
- The detailed study of the origin of nucleon spin and its connection to the gluon.

Near-term Program: For FY 2003, RHIC will run about 22 data-taking weeks for the heavy ion and polarized proton physics programs, following advice on its physics considerations and program recommendations given during the August 2002 Program Advisory Committee meetings. For the FY2003 run, the heavy ion program will continue with deuteron-Au collisions in RHIC, as well as polarized proton beams for spin physics. This choice of running conditions, as well as those for subsequent years, will optimize the physics output of the RHIC facility program. BNL will continue efforts to improve the collider's and detectors' performance.

Long-term Program: It will take at least ten years to fully explore the prospective richness of RHIC phenomena and, if they are as rich as anticipated, the lifetime of the program could stretch beyond twenty years. The four existing RHIC detectors (BRAHMS, PHENIX, PHOBOS, and STAR) represent an optimum diversity and complement each other. Like all programs in basic science, these detectors and the accelerator facilities that produce the colliding beams will evolve with time, following the unfolding directions in science. The RHIC program will accommodate this evolution through a program of systematic upgrades that assures that RHIC science is at the frontier of discovery. This continuous evolution will be punctuated by major improvements, such as constructing major new detectors or significantly modifying the existing ones, significantly improving the accelerator to enhance beam parameters, such as luminosity, and new capabilities, such as electron collisions in the RHIC ring that can qualitatively expand the horizon of RHIC exploration. The program will benefit from a fourfold increase in average luminosity during this programmatic evolution and, by means of full-energy electron cooling, realize an additional factor of ten in average luminosity growth by about 2010, as an early goal of the eRHIC Project. The eRHIC Project also will advance the program greatly by bringing 10 GeV electron beams into collision with heavy ion beams by about 2012, as the eRHIC project's prime goal. The enhancements to the eRHIC facility also will include important upgrades to two of the existing RHIC detectors; at least one more new detector is expected to be required for eRHIC collisions as the program evolves.

All the research groups doing experiments at RHIC can access the powerful computers and data storage facilities of the RHIC Computing Facility (RCF). The RCF records, archives, and serves as the computation resource for data reduction and analyses of experimental data obtained from all the detectors in the RHIC facility. The RCF began operations in FY 2000 and will continue to grow in power as the needs evolve. We developed, and are implementing, a detailed plan for maintaining this capability over the next decade of RHIC operations.

5.1.2 Alternating Gradient Synchrotron (KB/KA)

Present Program: The Alternating Gradient Synchrotron (AGS) produces the world's highest intensity, high-energy proton beam and includes the world's largest superconducting magnet at the muon g-2 experiment. The AGS also serves as the injector accelerator for the RHIC facility, providing beams of heavy ions and polarized protons to maintain the RHIC colliding beams. Research at the AGS increases our understanding of the nature of matter. It also continues its historical mission as the pivotal accelerator in a complex of machines that produce particle and ion beams for many non-RHIC scientific users at BNL. Users at the AGS accelerator complex represent several scientific communities including particle and nuclear physics, radiobiology, materials sciences, and advanced accelerator science. The AGS can accelerate heavy ions up to 11 GeV/atomic-mass-unit and can produce polarized proton beams that support a RHIC Spin Physics Program as part of the RHIC nuclear science mission. At the lower energy end, short-lived isotopes for medical research are produced using the proton linac, and various industrial items are tested with Megavolt ion beams at the Tandem van de Graaff.

Near-term Program: Since 1999, the prime mission of the AGS has been to inject heavy ions into RHIC on an as needed basis (about twice a day). Through FY 2002, the AGS has provided beams for experiments of exceptional scientific merit on a case-by-case basis, as proposed by the Laboratory, and approved and funded by the DOE program sponsor. As a result of the FY 2003 Presidential Budget, BNL was instructed to cease AGS operations for the user community because of the DOE's severe budget concerns in the High Energy Physics program. This agency decision came as a great shock to the AGS community and they have taken steps to restore the program to at least a fraction of its former activity level. Their action, if successful, will enable the AGS program to continue producing frontier basic research in particle physics. However, until these decisions are made, the AGS capabilities will continue to be made available to other agencies under the condition that such work does not interfere with its prime mission as injector to RHIC. At present, NASA supports a radiobiology research program using heavy ion beams and DOE-NNSA supports a proton radiography experiment. The DOE's Nuclear Physics Division authorizes this compatible use for Work for Others.

Long-term Program: The AGS provides the world's best venue for exploring very rare phenomena in particle physics because of the exceptional intensity of the high-energy proton beams. In FY 2004, the AGS is expected to embark on the "Rare Symmetry Violating Processes" (RSVP) project, a plan to build and operate experiments that will investigate rare phenomena of compelling interest to particle physics. RSVP is a Work For Others Program that will be sponsored by the National Science Foundation. In addition, several important experiments using pion, kaon, and muon beams are planned at the AGS for particle and nuclear physics users. Three of these experiments were approved, initially funded, and started by the DOE; others were moving through the approval process before the decision to cease the HENP operations of the AGS. NASA expects to continue the radiobiology program at the AGS and expand the program with the new Booster Applications Facility that will be completed in FY 2003 specifically for NASA's radiobiology program.

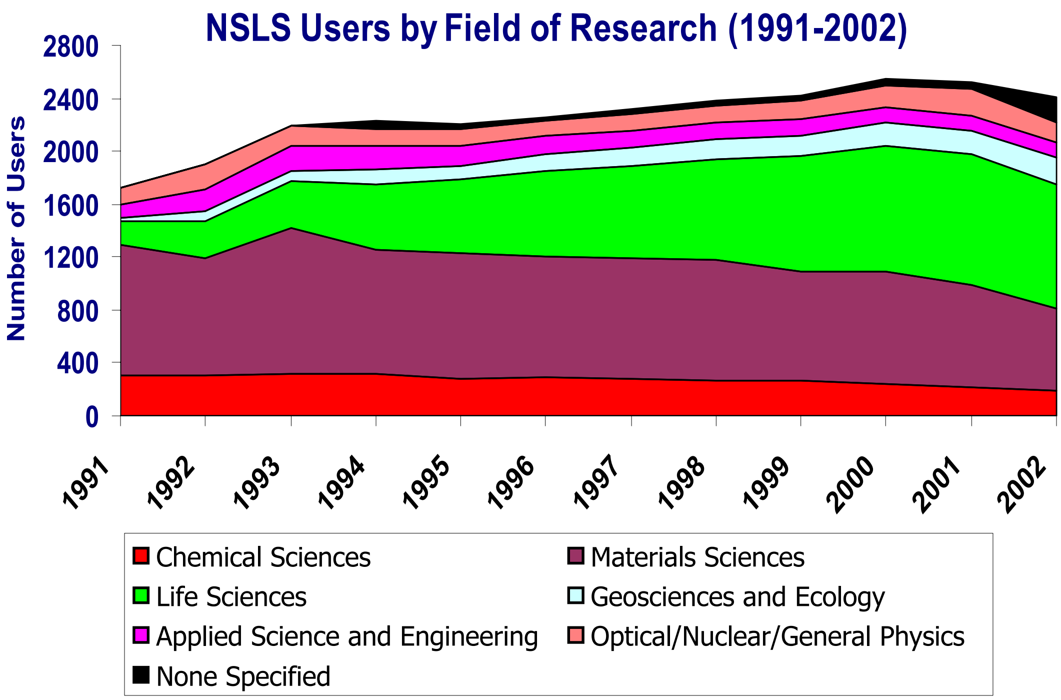
BNL also is planning to propose a high-intensity neutrino beam facility based on upgrading the AGS to a 1MW (or greater) target capability. Discussions were held with members of the particle and nuclear physics communities and with potential agency sponsors of a BNL neutrino program. Preliminary investigations indicate that this program could be competitive with any rival plan in Europe or Japan if the 1 MW level of beam power could be reached in the next decade, and if a complementary neutrino-detector initiative is undertaken at the same time to exploit the AGS beam. Noting the important DOE Office of Science Future Projects Initiative that is being pursued in late 2002 and early 2003, it appears that both the VLB Super Neutrino Beam proposed by BNL and a Megaton target detector (UNO) proposed by Stony Brook University are included in the study process; both will be vigorously pursued as conceptual designs. It is highly likely that BNL and Stony Brook will develop a full collaboration to accomplish neutrino physics with the VLB beam and the UNO detector combining to carry out the neutrino oscillations physics program. BNL will continue to study the possibility for the VLB Super Neutrino Beam.

5.1.3 National Synchrotron Light Source (KC)

Present Program: The National Synchrotron Light Source (NSLS) is one of the principal DOE synchrotron sources. Light sources are essential tools for research in many disciplines. Initially, research focused mainly on material problems and chemical processes, but expanded more recently to include large biological systems and environmental problems. The NSLS is devoted to producing synchrotron radiation, developing new radiation sources, and developing new applications of this radiation. Currently, it provides high-intensity infrared, ultraviolet, and x-ray radiation to approximately 70 user beamlines. In

2002, more than 2400 users from over 400 national and international institutions came to the NSLS; Figure 5 shows their distribution by discipline.

Figure 5 - Distribution of NSLS Users by Discipline



Near-term Program: To enhance the NSLS's capability to meet increasing and changing user demands, major upgrades were completed recently or are in progress. Two new RF cavities are being installed in the x-ray ring. A new digital orbit feedback system, which significantly improved orbit stability on the VUV ring, is being implemented on the x-ray ring. A new NIH-funded beamline, X6A, for structural biology was completed by the NSLS, and is ready for user operation. A major initiative is underway to upgrade all the insertion device beamlines on the x-ray ring to meet the demand of new scientific programs: (1) a new high-resolution monochromator was installed and commissioned for the soft x-ray undulator beamline X1B; (2) the superconducting wiggler beamlines at X17 are being reconfigured to increase experimental throughput; (3) on X21, photon beam transport is being provided to establish two new end-stations for materials science research; (4) on X25, a state-of-the-art 9-cell CCD detector was installed; (5) a new in-vacuum undulator, with better energy tunability, was installed in X13 for microbeam applications; (6) a new in-vacuum undulator beamline, X29, is being constructed to provide higher brightness radiation for structural biology, (7) an in-vacuum undulator beamline, X9, will be developed to provide higher brightness radiation for nanoscience users; and, (8) development was started on in-vacuum superconducting undulators. The higher field provided by the superconducting magnet will eliminate the tuning gaps of current in-vacuum undulators.

As the synchrotron radiation users community expands, most new users will not be experts in synchrotron instrumentation and techniques, so the NSLS will need to increase its role in all aspects of the user program; we face a growing need to support and operate more beamlines. Accordingly, a new user science division was created to better communicate with existing and potential users, increase user support at NSLS and PRT beamlines, identify and coordinate new scientific opportunities, and develop optics and detectors. Several major initiatives were undertaken or funded in collaboration with the user community that require significant involvement by the NSLS:

- Consortium for Materials Properties Research in Earth Science: NSF in FY 2002 funded a new national resource for high-pressure research based at Stony Brook University. The program's centerpiece is high-energy x-ray diffraction and infrared study of materials under high pressure at the NSLS.
- Powder Diffraction Center: The NSLS is organizing a center for x-ray powder diffraction, with four dedicated instruments: a high resolution instrument, a high throughput instrument, an instrument optimized for high pressure and pair-distribution function, and one with combined capability for powder diffraction and x-ray spectroscopy.
- Center for Environmental Molecular Science: Funding was approved to establish a Center for Environmental Molecular Science, proposed by a Stony Brook-BNL collaboration, to address the molecular-scale reaction mechanisms governing the interactions of selected environmental contaminants with mineral and mineral-like phases. The experiments will rely heavily on a suite of synchrotron techniques at the NSLS.
- Nanoscience users program: The NSLS is working closely with the CFN to structure the general user program, and to meet the demand for synchrotron techniques by nanoscience users. New synchrotron tools will be developed specifically for their programs.
- Catalysis beamlines consortium: NSLS has many catalysis researchers from universities, government laboratories, and industry. As part of the proposed Catalysis Research Institute of BNL (Section 4.5), NSLS plans to upgrade and optimize a suite of beamlines, ranging from infrared to x-ray, for this research.

Long-term Program: Extensive development programs within the existing NSLS accelerator complex will improve the stability, reliability, and lifetime of electron beams, and develop new insertion devices to modulate polarization state and produce even brighter photon beams. Equally important are programs to develop new beamline instrumentation, including beamline optics, monochromators, and especially detectors that will let users take full advantage of the NSLS's unique research capabilities. However, since more of the users require higher brightness, a combination of a higher brightness source and many more insertion device beamlines will be needed to meet these demands. Accordingly, the NSLS is aggressively pursuing a major upgrade of the facility (Section 4.3).

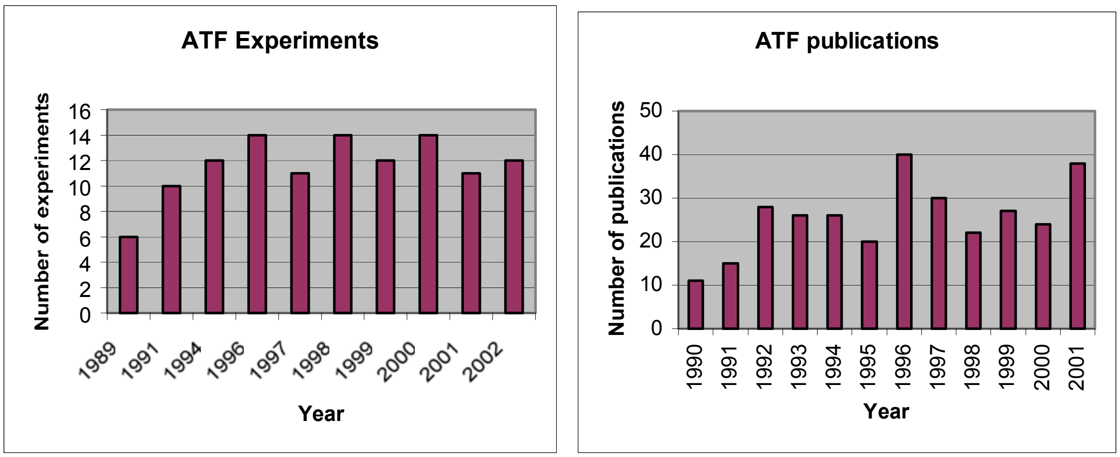
5.1.4 Accelerator Test Facility (KA)

Present Program: An important component of the success of the DOE is innovative accelerator R&D. Exploring the physics of beams requires experimental facilities where scientists from universities, national laboratories, and small businesses can experiment with new ideas and techniques. Such facilities are expensive and cannot be duplicated at every single research establishment. The existing large facilities, such as the synchrotron light sources, are dedicated to thousands of users and are not suitable for accelerator development. Accelerator and beam scientists need access to their own user facility, and the Accelerator Test Facility (ATF) is such a facility.

The ATF is dedicated to long-term R&D on the Physics of Beams. The ATF provides the electron beam and infrastructure for supporting many experiments and continuously characterizing the electron beam, and for developing manipulation tools. The core capabilities include a high-brightness photo-injector electron gun, a 70 MeV linac, high power lasers synchronized to the electron beam to the picosecond level, four beam lines (most with energy spectrometers), and a sophisticated computer control system. The ATF has a preeminent position in developing RF photocathode electron gun technology, laser acceleration of electrons, and has made a significant impact on the pursuit of electron beam development for advanced accelerator concepts, including Free Electron Lasers (FEL).

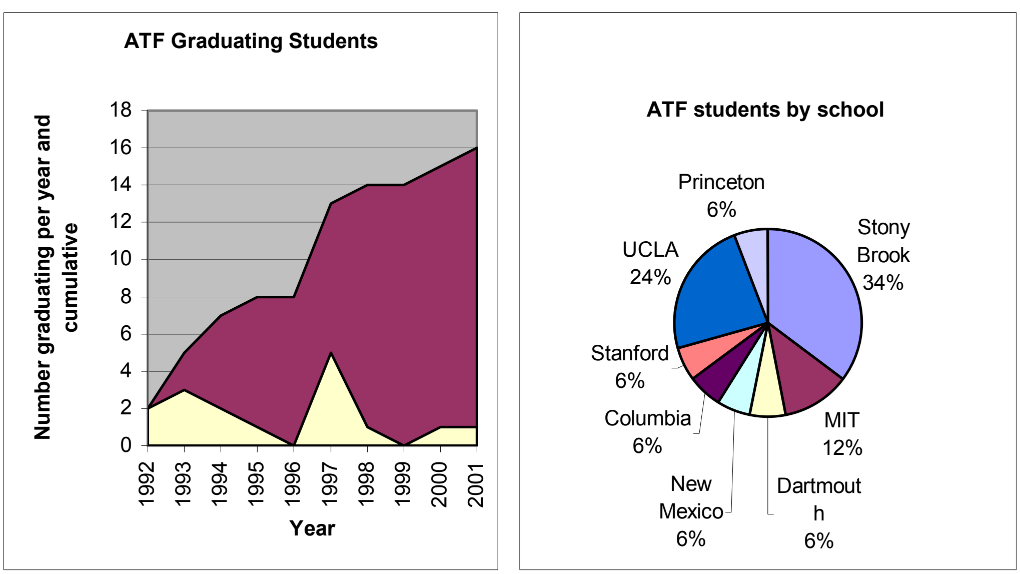
In the first few years of operation, the number of experiments grew rapidly. Later, it reached a steady state, with experiments being completed at about the same rate that new experiments were approved. This can be seen in Figure 6, along with the number of publications.

Figure 6 - The Number of ATF Experiments and Publications as a Function of Time



The ATF makes a significant contribution to educating graduate and postdoctoral students in accelerator physics. Figure 7 shows the number of students graduating per year, the cumulative number of graduations, and distribution by school.

Figure 7 - Graduate Students Statistics for the ATF
These figures are for year of graduation (light) and cumulative total (dark) and their distribution by school.



Seventy researchers from universities, national laboratories, and industry used the ATF in FY 02. These researchers conduct R&D on Advanced Accelerator Physics and study the interactions of high power electromagnetic radiation and high-brightness electron beams, including laser acceleration of electrons and Free-Electron Lasers. Other areas of investigation include the development of electron beams with extremely high brightness, photo-injectors, electron beam and radiation diagnostics, and computer controls. The ATF hosted two important proof-of-principle FEL experiments. The BNL-NSLS High-Gain Harmonic-Generation (HGHG) experiment, in collaboration with ANL-Advanced Photon Source, demonstrated this unique approach to highly coherent FEL radiation. The VISA experiment tests and characterizes SASE Free Electron Laser operation in the visible region, where high quality optical diagnostics are readily available. This is done in collaboration with SLAC, LBNL, LLNL, and UCLA. The VISA FEL exhibited a very high gain and saturation, and provided unique measurements of micro-bunching and non-linear harmonic generation.

Some notable recent results include the staging of laser accelerators in the Staged Electron Laser Accelerator (STELLA) experiment and achieving a record hard photon flux in picosecond pulses from the Compton Scattering experiment. Research in the STELLA experiment now pursues another milestone in laser acceleration: the generation of mono-energetic laser-accelerated electrons. The Compton experiment, done in collaboration with Japanese scientists under the US/Japan collaboration in High-Energy Physics, demonstrated channeling of the CO_2 laser using a plasma lens in a capillary tube. Next year we expect to enter the plasma acceleration field using the new terawatt picosecond CO_2 laser that operates with a long pulse mode.

We improved the facility's infrastructure. We measured the phase space distribution of a picosecond slice of an electron beam in transverse and longitudinal tomography, improved the photocathode drive laser, enhanced the beam brightness of the ATF, improved the phase and amplitude stability of the beam, achieved record performance of the photocathode, and improved diagnostics, power supplies and services. A major effort is underway to upgrade the computer control system to accommodate the terawatt CO_2 laser.

Near-term Program: Next year we hope to complete upgrading the computer control system, with improvements in the electron beam brightness and associated beam diagnostics, install a bunch compressor, upgrade the high-energy beam transport system, begin operations with the terawatt picosecond CO_2 laser, and increase the facility's energy to 120 MeV.

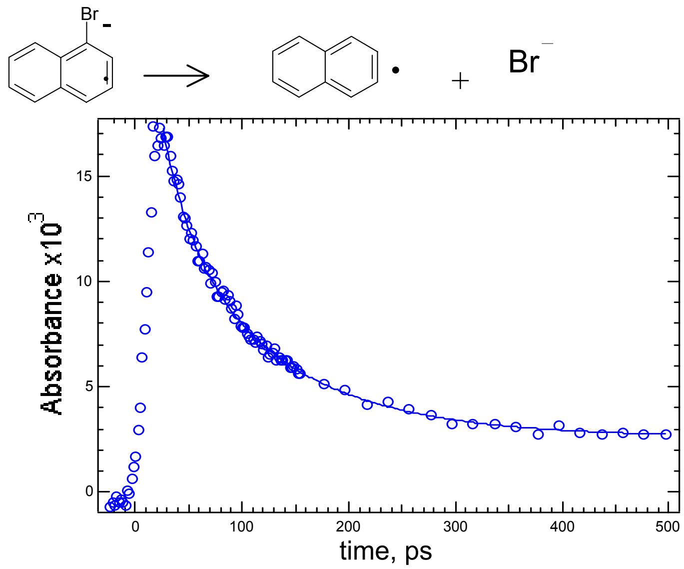
Long-term Program: In the next five years we expect to construct a new Experimental Hall to house more beam lines, increase the beam energy to 200 MeV, and construct a strong laser field experimental station for laser experiments that do not require the electron beam (such as generating GeV ion beams, plasmas).

5.1.5 Laser Electron Accelerator Facility (KC)

Present Program: The new Laser Electron Accelerator Facility (LEAF) significantly enhances Brookhaven's instrumental capability for research in radiation chemistry and photochemistry. LEAF delivers synchronized picosecond electron and photon pulses, and provides a means to study the fundamentals of ionization in condensed media on fast time scales. Two operational detection systems obtain transient absorption data either rapidly with ~ 1ns time resolution, or with 7 ps resolution in more time-consuming "pulse-probe" experiments. An exciting ultrafast single-shot detection system was demonstrated in principle with LDRD funds.

Figure 8 shows that LEAF's pulse-probe data measures rates of dissociation of chemical bonds more than a 100 times faster than any previous reports for this type of reaction. This type of molecule, an aromatic halide, is important in synthetic chemistry. Many chemicals are made in reactions that break chemical bonds between carbon and chlorine or bromine (Br) to enable the formation of new bonds. Because even small improvements in the efficiencies of these reactions could save industry millions of dollars annually, chemists have sought to understand what controls the speed at which these bonds break when an electron is added to the molecule.

Figure 8 - LEAF: Capture of an Electron Leads to Fast Breaking of a Bond



$\tau_{decay} \sim 70$ ps

Future Program: Experiments combining electron pulse and laser pulse excitation are anticipated to achieve ~ 0.1 ps time resolution. This will give LEAF a unique ability to combine the well-defined energetics of accelerator experiments with the high time resolution of laser experiments. Concurrently the performance of existing detection systems will be improved. The LEAF facility also holds significant promise for new studies related to radiation-induced chemistry relevant to electron transport in molecular-scale electronics and devices in support of BNL's nanoscience program. A new ultrafast single-shot detection concept will be explored that has potential to make LEAF the world center for studying many types of fast reactions.

5.1.6 Transmission Electron Microscopy Facility (KC)

Present Program: The Transmission Electron Microscopy (TEM) facility has a unique and powerful 300kV field-emission high-resolution microscope with capabilities of transmission and scanning high-resolution atomic imaging, magnetic imaging, spectroscopy, energy filtered electron diffraction, and electron holography. The TEM research activities focus on understanding nanoscale crystal structure and structural defects, and their role in determining the physical properties of advanced materials, such as high temperature superconductors, permanent magnets, transition-metal oxides, and other nanostructured materials.

BNL developed a novel interferometric technique based on coherent electron diffraction, coupled with imaging, to measure lattice displacement in crystal defects with unprecedented accuracy down to 1 picometer. This is about a tenfold improvement over any existing technique. BNL also developed and implemented phase retrieval methods, including electron holography, to map valence electron distribution and interfacial charge variation in superconductors. Using various advanced magnetic imaging methods, researchers studied the *in-situ* magnetic behavior and local induction distribution as a function of temperature and field in hard magnets, as well as in magnetic nanoassemblies fabricated in-house.

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Near-term Program: BNL is extending its unique abilities in structural characterization to address important areas in materials science. Besides the continued study of the electronic and magnetic structure of functional materials, BNL will explore and develop new approaches to the phase problem for non-periodic objects that have fundamental importance in microscopy, both for electron microscopy and synchrotrons. We will continue to develop TEM based electron lithography to fabricate tailored structures that exhibit merging optical and magnetic properties because of their fine length scale and to understand exchange coupling and switching behavior of the materials. We are acquiring of a state-of-the-art omega filter microscope with a monochromator (funded by NYSTAR and DOE). The new instrument will provide < 0.2eV energy resolution that will boost our research on nanoprobe electron energy-loss spectroscopy.

Long-term Program: Our mission is to develop and apply advanced techniques of quantitative electron microscopy to fundamental problems in materials science. The TEM facility and expertise complements the capabilities in Physics, NSLS, Chemistry, and Biology, and is an important component of the proposed BNL Nanoscience Center. The following are key areas of investigation over the next few years:

- The study of atomic structure, bonding characteristics, and charge variation at nanostructure interfaces with unprecedented spatial resolution using quantitative electron diffraction, imaging, and electron energy-loss spectroscopy, Z-contrast, and structural modeling techniques including those developed at BNL.
- *In-situ* experiments and dynamic observations of magnetic, ferroelectric behaviors, and shape-memory effects of various functional materials and devices, including p-n junctions, under controlled stress, magnetic, and electric fields.
- Nanoscience and technology related areas, including fabricating quantum-structure using electron lithography with spatial resolution (line width) below 5nm.
- Development of a single atom imaging and imaging analysis technique in conjunction with BNL biologists for biology and materials research.
- Expanded collaboration with scientists at Stony Brook, Columbia, and Princeton to work on semiconductors, nanomagnetic composites, polymers, and biomaterials.
- Development of a new generation achromatic microscope (<0.07nm spatial resolution and <0.1 energy resolution) incorporated with aberration correctors and a build-in scanning tunneling microscope (or magnetic force microscope) to build a true nano-lab inside the microscope for manipulating structures and measuring properties. The Laboratory is a partner in the TEAM (Transmission Electron Aberration-corrected Microscope) project that involves research and development in collaboration with five BES-sponsored electron beam microcharacterization centers. Partner laboratories include Frederick Seitz Materials Research Laboratory, the National Center for Electron Microscopy at Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, and Argonne National Laboratory. Parallel R&D activities focus on UHV experimental modules and microelectromechanical system (MEMS) stage design, sub-Angstrom Z-contrast imaging and atomic resolution electron energy loss spectroscopy (EELS), and electron optics modeling. The BNL emphasis is detector development and position sensitive coherent electron detection. The TEAM project is highly collaborative and the BNL program interfaces with the partner laboratories through quarterly meetings of the directors and a program allowing extended exchange visits among researchers at the institutions.

5.2 Science and Technology Programs

While BNL operates the world's frontier facilities for nuclear science and one of the world's most productive coherent short wavelength light sources, these facilities rely on the R&D programs at BNL to combine accelerator technology and basic science, ensuring continued leadership in the next generation of accelerator based beams of light and matter. Other R&D programs at the Laboratory lead in using these facilities to advance knowledge and take advantage of the Laboratory's wealth of talent and capabilities for discovery and issue-oriented research. These fundamental components, large scale or complex facilities, supporting technologies, and science programs link the facilities to the users and to the DOE's missions.

For planning, our emphasis is on interdisciplinary themes and their relation to the DOE's missions, user needs, and BNL's core capabilities. These themes provide a focused framework and identify the "bright spots" of the Laboratory's research activities within a very broad spectrum. The following sections describe BNL's programs and, in conjunction with the program initiatives, define the future direction for our science and technology endeavors.

5.2.1 Nuclear and High Energy Physics (KA/KB)

The DOE Office of Science, High Energy, and Nuclear Physics program sponsors experimental and theoretical Nuclear and High Energy Physics. Scientists in the Physics Department conduct most of the R&D, while solar neutrino research is managed by the Chemistry Department.

5.2.1.1 Nuclear Physics - Quark Gluon Plasma, Solar Neutrinos, and Spin Physics (KB)

Present Program: BNL is home to a large and strong research program in nuclear physics, supported by the DOE's Nuclear Physics Division, a program that complements the user facilities operated by the Laboratory for the benefit of the entire nuclear physics community. In the experimental areas of research, BNL is responsible for operating and maintaining the RHIC's four experimental detectors as fully functional forefront instruments. A second, equally important, role is Brookhaven's leadership program in nuclear physics experimental work covering the entire RHIC-based heavy-ion and spin physics program. For this second mission, BNL maintains four strong RHIC experimental research groups based on the RHIC detectors (BRAHMS, PHENIX, PHOBOS, and STAR). During FY 2002, the detector groups operated and maintained all four detectors and participated in the second RHIC Collider data-taking run using full-energy (100 GeV/amu) gold on gold colliding beams and conducting the first runs with polarized proton beams. All the RHIC experiments are supported by the powerful computers and data storage facilities of the RHIC Computing Facility (RCF) that record, archive, and serve as the computation resource for data reduction and analysis of experimental data from all the RHIC detectors.

The Laboratory is building a RHIC Spin group to provide leadership for the RHIC spin physics program. Nuclear physics staff also supports a limited set of fixed-target medium-energy user experiments that can be explored with secondary beams (kaons and pions) from the AGS. These experiments focus on important special topics, particularly the study of hypernuclei. In FY 2001, using low energy kaon beams, two experiments were conducted on the non-mesonic decay of lambda - He^4, and on hypernuclear gamma rays; they were concluded in FY 2002. The future of the hypernuclear physics program at BNL is uncertain and may be phased out and staff scientists re-assigned to other research areas such as the RHIC spin program.

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A third area of nuclear science receiving significant attention in recent years is solar neutrino research, specifically the search for neutrino flavor oscillations and neutrino mass. For a decade, BNL has actively participated in GALLEX at the Gran Sasso Laboratory in Italy, and since 1996 has been involved in running the Sudbury Neutrino Observatory (SNO) at the Creighton Mine in Ontario, Canada. The first phase of data acquisition for SNO, with one kiloton of ultra-pure deuterium oxide (D_2O), began in October 1999. The first published SNO results confirmed that the model of the sun predicts the number of electron neutrinos that the sun produces, and that transformation to other neutrinos occurs as they travel from the sun to the earth. Research continues with the SNO Experiment in FY 2003 and 2004. We held preliminary discussions about participating in the LENS neutrino concept, an international collaboration formed to study of neutrinos from the solar basic pp cycle.

A world-class nuclear theory group is working on Quantum Chromodynamics (QCD), including phenomenological models of matter at high energy density, the high-energy limit of hadronic interactions and nuclear structure, and hypernuclei. This work is done in close collaboration with nuclear theorists in the RIKEN BNL Research Center (RBRC) and other nuclear theory groups in the Long Island area (Columbia, Stony Brook University, and Yale). The RBRC, located at BNL, is a complementary theory and experimental physics institute. Its scientists are an integral part of the nuclear physics research at BNL and are funded primarily by the RIKEN Institute of Wako, Japan. RBRC and BNL scientists, together with outside users, form the RHIC Spin Group.

Nuclear Physics research at BNL includes the polarized-beam/polarized-target Laser Electron Gamma Source (LEGS) Experiment at the National Synchrotron Light Source (NSLS). The LEGS researchers are studying the electromagnetic structure of the nucleon, including the nuclear structure around the delta resonance region. These studies will provide unique new data for polarized photons interacting with polarized hydrogen and deuterium (frozen spin) targets developed by the collaboration. The LEGS data will be used to measure the spin-polarizability and Gerasimov-Drell-Hearn spin-sum rules. Future work at LEGS will involve elucidating pi^0 production from polarized neutrons from the same frozen spin targets. The current LEGS program has an anticipated lifetime of about three years.

Future Program: The nuclear physics research mission includes further strengthening of theRHIC based experimental groups and continuing both experimental and theoretical nuclear physics in support of the evolving RHIC, and LEGS programs. During FY 2002, BNL made progress in consolidating a strong RHIC Spin experimental group in the Physics Department to provide intellectual strength to the spin physics program comparable to that already in place for the relativistic heavy-ion program. In the future, the experimental RHIC detector groups will lead planning for the evolution of detectors as the RHIC physics program advances and new results and research directions appear. The BNL-based research groups will be foremost in defining and accomplishing the work, in cooperation with the entire RHIC experimental community.

At SNO, the emphasis shifted in 2001 from measuring the neutrino charged-current (CC) and elastic-scattering interaction in pure D_2O, to searching for evidence for the neutro-current (NC) interaction. This was accomplished, first by adding sodium chloride (NaCl) to the D_2O to accentuate the NC signal, and in 2002, after removing the NaCl, to inserting ^3He filled neutron counters into the D_2O. If evidence is found that the NC signal is greater than the CC signal that will constitute definitive proof for the occurrence of neutrino oscillations, since some electron-neutrinos from the sun will have transformed into the other known neutrino flavor.

The two real-time solar neutrino detectors that have operated to date, Super Kamiokande and SNO, have thresholds of ~ 5 MeV. They are sensitive only to ^8B neutrinos. Only the radiochemical solar neutrino detectors had thresholds below 1 MeV and could observe ^7B (Homestake) neutrinos and pp and ^7B neutrinos (GALLEX and SAGE). A concept is under study at BNL for a new neutrino detector with a very low threshold, ~0.25 MeV, the Low Energy Neutrino Spectrometer, LENS. The design goals for this detector are to measure the energy spectra and fluxes of pp and ^{7}B neutrinos in real time, to complete our knowledge of solar neutrino interactions. R&D on LENS continued through 2002, with the goal of designing and building a prototype in mid 2003. If this proof-of-principle test is successful, a proposal will be made to the DOE in 2004-2005 for ~100 ton LENS.

5.2.1.2 High Energy Physics - Standard Model Tests and Rare Processes (KA)

Present Program: For more than forty years, BNL has been a strong center for experimental and theoretical research in high-energy physics. Now, the BNL research groups lead and support precision experiments at the AGS and participate as users in high energy physics experiments at other facilities, such as the D0 Experiment at Fermilab and the ATLAS Experiment at the CERN Large Hadron Collider (LHC).

To accomplish this research mission, the DOE's Division of High Energy Physics supports two experimental groups (Electronic Detector and Omega) as well as a particle theory group. These groups are expected to continue their currently defined mission at least for the next decade. BNL also supports a small experimental group for advanced accelerator physics in the Center for Accelerator Physics (CAP). CAP scientists are engaged in a program of accelerator R&D to explore the technical feasibility of muon colliders, muon storage rings, and high-power conventional sources (horn-focused) of neutrino beams.

Future Programs: The Electronic Detector Group continues a program to study rare kaon decays to uncover experimental manifestations of CP-violation in these decays. Rare kaon decays represent both an important experimental window into the nature of CP-violation and a tool for exploring physics beyond the Standard Model. The latter will continue to be an important topic for many years, and BNL's experimental group will continue to be a leader in this field. The next experiment in this program, E949, will make the first definitive measurement of the very rare Kaon decay, $K^{+} \rightarrow \pi^{+} \upsilon \overline{\upsilon}$. The next experiment is likely to be the companion neutral decay $K^{0+} \rightarrow \pi^{0} \upsilon \overline{\upsilon}$. BNL expects to be funded for this experiment (called KOPIO) as one of two experiments approved under the "Rare Symmetry Violating Processes" (RSVP) Major Research Equipment (MRE) initiative by the National Science Foundation (NSF). The RSVP project is anticipated to begin in FY 2003 or FY 2004. The second of the two experiments is called MECO, which stands for "Muon to Electron Conversion", a process that is forbidden in the Standard Model of particle physics but that is allowed under many non-SM alternatives. Indeed, the ability of the RSVP to probe mass regimes far above the energy of current or planned accelerators is likely to ensure that this approach to the energy frontier may outrun all of the planned high-energy machines in the decades to come. BNL is pursuing this promising pathway with several universities.

The Omega group engages in experiments outside BNL, the D0 Experiment at Fermilab and the ATLAS Experiment at CERN's LHC. They constitute the leading edge at the energy frontier of particle physics, and the BNL group has contributed strong intellectual leadership, as well as important hardware and software for the success of the experiment. At present, BNL is the host Laboratory for the U.S. ATLAS Construction Project, the U.S. ATLAS Computing Project, and will provide the oversight and operations management for all U.S. scientists participating in the ATLAS experiment once it becomes operational and serves as a source of data on high energy physics. Members of the Omega Group take part in the muon g-2 experiment at the AGS, producing a new precision measurement of g-2 that constitutes one of the best near-term probes for revealing evidence for physics beyond the Standard Model. In FY 2001, the collaboration published results that gave the first indications of a deviation from the Standard Model, but this finding later was undercut when the prediction of the Standard Model theory was revised to decrease the discrepancy. Further results in FY 2002 upheld findings from FY 01, and additional runs might happen in future years. This experiment may be succeeded by a new experiment using the muon (g-2) ring to provide new upper limits on the muon neutrino mass. A second smaller effort of the Omega group is their participation in the MINOS neutrino experiment under construction at Fermilab. This experiment will confirm the neutrino oscillations observed in the Super Kamiokande experiment now underway in Japan and will provide better statistics on the ν_μ to ν_τ oscillation process. The Omega Group's plan for the next 10 years is to explore particle physics at the energy frontier in D0 and ATLAS, a natural role for BNL given our role as host Laboratory for all U.S. ATLAS groups.

After identifying at least two exotic mesons, the Quark-Gluon Spectroscopy Group is in the final stages of data analysis, since its AGS-based experimental program terminated in FY 1999. This group is presently exploring new research directions.

The BNL High Energy Theory group will continue to pursue a wide range of theoretical studies in particle physics. They presently include electro-weak studies, collider phenomenology, perturbative Quantum Chromodynamics (pQCD), lattice gauge theory, and field theory with emphasis on finite temperature effects. A recent example was the calculation of 2nd order weak effects contributing to the muon g-2 value, an important contribution to the theoretical understanding of this number and one that enabled the muon g-2 value to be used as a probe for physics beyond the Standard Model. The future work of the Theory group is expected to continue along the same general pattern.

5.2.2 Advanced Facilities - Concepts, Designs and Instrumentation (KA/KB/KC)

Development of accelerators, detectors, and sources, along with R&D on superconducting magnets are essential core competencies for the Laboratory. These support the existing Science & Technology facilities here and at other DOE Laboratories, and are essential for the effective development of future DOE facilities.

5.2.2.1 Accelerator Physics

Present Program: Brookhaven National Laboratory, with its suite of diverse accelerators (i.e., the AGS, RHIC, NSLS, Tandem, and ATF) has one of the largest concentrations of innovative accelerator scientists in the U.S. BNL's staff also maintain a modest graduate teaching program in accelerator physics.

In addition to improving and upgrading the accelerators at BNL, our accelerator scientists pursue a program of continuing accelerator physics research using the RHIC, AGS, NSLS, and ATF. Experimental studies of advanced concepts are performed in the Laboratory's unique user facility for in-house and external accelerator experiments, the Accelerator Test Facility (ATF). The Center for Accelerator Physics (CAP) at BNL is the institutional infrastructure for discussing and coordinating accelerator science at the Laboratory. CAP organizes workshops, seminars, special studies, and projects to integrate and advance future accelerator programs at BNL. All BNL's accelerator scientists are encouraged to become members of the CAP.

BNL designs accelerators and produces accelerator components for outside clients. This work includes the complete design and construction of the Accumulator Ring and Beam Transport for the DOE's Spallation Neutron Source, a collaboration that will be active through 2006. BNL is constructing the new "Booster Applications Facility" (BAF) to continue and expand the current NASA-funded radiobiology program that has been active for the last seven years at the AGS. The BAF Project will be completed in FY 2003 and will offer NASA a new venue for performing radiobiology experiments in an expanded research program. The design of a 70 MeV cyclotron for research and isotope production was completed for a potential DOE-NE supported construction project.

We completed the design and costing of a 250 MeV rapidly cycling medical synchrotron for cancer therapy and are forming an industrial partnership to market and construct such a facility. Several university hospital facilities, such as the University of Pennsylvania, expressed interest in having an accelerator facility. We are presently designing the beam transport and gantry optics for the Rinecker Proton Therapy Facility, Munich, Germany, under a CRADA with an industrial partner.

BNL's staff participate in the "Neutrino Factory and Muon Collider Collaboration," an international group of accelerator physicists who pursue R&D on the concept of capturing an intense beam of muons in an accelerator/storage ring complex. A successful design for a muon storage ring could provide the means to precisely characterize neutrinos or, at a later stage, form a basis for a muon-muon collider to extend the frontier of particle physics beyond the era of CERN's LHC. BNL's CAP serves as a focus for this work. The goal of the collaboration is to explore the feasibility of a multi-TeV (Trillion electron volts) collider. The national program includes computer simulation and experiments for creating intense muon beams from high-power proton accelerator beams, dampening the relative motion of muons in the bunch (cooling) to reduce the emittance of the beam, and acceleration to a high energy for injection into a storage ring. These studies will resolve the most critical technical questions presently standing in the way of a research facility where muons could be stored in a race-track ring to create an intense beam of high energy neutrinos for neutrino physics, or circulated in a collider facility where muon-muon collisions could be used to investigate TeV scale high energy physics. In addition to simulations and other design studies, BNL has a specific mission within this collaboration to conduct an experimental targeting study, E951 using high-intensity proton beams from the AGS. At BNL's AGS, the first phase of E951 conducted in FY 2001, showed the potential feasibility of using jets of liquid mercury as a high-power proton beam target for producing low-energy muons. The AGS serves as a crucial test bed for the new approaches and technologies needed by any proton source suitable for a future muon storage ring or collider. The group also is studying the value to neutrino physics of a very intense, horn or solenoid focused neutrino beam using an upgraded AGS as the proton driver. Preliminary results indicate that target power up to 2 MW is achievable by replacing part of the present 200 MeV linac with a superconducting 300 MeV section, installing an accumulator ring in the AGS tunnel, and installing a new AGS power supply that will allow 2.5 Hz operation.

Future Program: New programmatic needs, such as electron cooling of RHIC ions and an electron-ion collider (eRHIC) are driven by the need for high power electron beams. Studies completed at the Budker Institute, Novosibirsk, Russia on the feasibility of electron cooling indicated that it is a viable approach. BNL agreed to collaborate with physicists from the Bates Laboratory, MIT in FY 2001 and expects to collaborate with other U.S. laboratories such as TJNAF and Cornell to develop the recirculating linacs and then to design a complete electron beam for the prospective eRHIC collider.

BNL's management commissioned a study during FY 2002 of the feasibility and value of a megawatt-class, AGS-based 1 GeV neutrino beam that would advance the study of neutrino oscillations and, ultimately, elucidate CP-violation in the neutrino sector. The horn or solenoid-focused beam would be aimed at a megaton-class neutrino event detector located 1000-3000 kilometers away from Long Island. Candidate target locations among others include the Homestake Mine in Lead, South Dakota, currently under consideration as the site of the U.S. National Underground Laboratory funded by grants from the National Science Foundation. Assuming the current studies turn out favorably, BNL could submit a first proposal to the DOE for the megawatt source as early as FY 2003.

These activities, plus the exploration of concepts for the future evolution of BNL's accelerator facilities, round out the spectrum of accelerator physics activities at BNL. In the future, all of these activities are expected to continue, their emphasis evolving with the needs of the Laboratory and in response to opportunities for BNL to contribute to the national program of accelerator R&D, design, and improvement.

5.2.2.2 Superconducting Magnet Research and Development

Present Program: Since the 1980s a primary BNL core competency is designing, constructing, and testing substantial numbers of large, superconducting magnets, especially for accelerator applications. As it was fully institutionalized during the development of the RHIC and SSC accelerators, this capability matured into a leading source of U.S. expertise. In parallel, the Laboratory also began a vigorous program of design for high temperature superconductors and magnets. Current R&D work focuses on the magnet requirements of future accelerator facilities, in addition to producing innovative ones for operating facilities.

Near-term Program: The current mission is to build and test a limited number of superconducting dipoles for the LHC Accelerator Project, to test all the superconductors for the CERN-based LHC accelerators, and to build spare superconducting dipoles, quadrupoles, and correction magnet modules as replacement magnets for use in RHIC, as needed. In addition to the baseline work on the RHIC magnet that will go forward for years into the future, BNL also is producing a few special purpose superconducting magnets for the Laboratory, as well as for external applications. BNL developed unique designs for helical dipole magnets for the RHIC Spin Program, as well as a direct wind technology, available only at BNL, for building interaction-region magnets for the HERA facility at DESY.

Working groups associated with both future hadron colliders and muon storage rings/colliders have been active in the past few years, and the generic requirements for magnets are available. For a 3rd generation hadron collider at a center-of-mass energy of 100 TeV, an interesting approach is based on 12 Tesla dipole magnets. The immediate technical challenge is to produce a dipole magnet able to operate at this field. The standard NbTi superconductor used over the past 20 years for accelerator magnets will not reach these fields, and so attention moved to both Nb_3Sn and high temperature superconductors (HTS). These materials are difficult to work with, but both materials can operate to these fields.

Muon Colliders pose a different set of challenges; the decay of the intense muon beams deposits a large amount of energy into the magnet. For this magnitude of magnetic field, the superconductor must be shielded from this radiation. High-temperature superconductors that exhibit very small temperature dependence when cooled to helium temperatures would be effective. A conceptual design of a magnet that removes the coils from the mid-plane was developed as an alternative to a large bore magnet where most of the aperture is filled with shielding.

During the past two years, production was completed on the helical dipoles and the DESY magnets. During FY 2001 and 2002, the first production LHC magnets were fabricated and successfully tested. In the area of high field magnets, BNL wound and tested several 1 m test magnets made with new superconductors to study magnetization effects, material degradation, and "quench" characteristics. These magnets were made with a variety of materials (HTS tape, HTS cable, Nb_3Sn cable) using vacuum impregnation. Tests are progressing to support the engineering design of a magnet able to withstand the mechanical forces at 12 Tesla.

BNL entered into an R&D collaboration with the GSI Laboratory, Germany to develop rapid-cycling superconducting magnets. The work will involve changes to the superconducting cable and the method of its manufacture into a coil. While the GSI-proposed in-house program determines the initial requirements, other potential applications are of interest to BNL. Preliminary discussions were held in

FY 2001 and 2002 with the Institute for High Energy Physics (IHEP), Beijing about supplying the micro-beta quadrupoles for their accelerator upgrade and with the management of the Linear Collider R&D program at SLAC, where BNL's expertise will be applied to the conceptual design of the final focus region where the 400 GeV electron positron beams will be collided.

Long-term Program: The long-term goal in high field magnet R&D is to demonstrate an HTS dipole magnet that achieves 12 Tesla in an accelerator quality fashion. BNL will continue work on a 12 Tesla dipole based on Nb_3Sn technology as a fall back technology, if needed. The present goal of this program is to demonstrate a muon collider style proof-of-principle magnet.

Plans are proceeding to increase the luminosity of RHIC by "cooling" the beams of heavy ions with electrons. This facility will include a solenoid magnet with tight tolerances on alignment and field uniformity. The Magnet Division will design and construct this magnet as part of its support to the RHIC program.

The Laboratory also is investigating the potential application of HTS to an ultra-high field NMR solenoid. Only HTS can reach the 24 Tesla-field level needed for a next generation device, but many issues related to stability and field quality need to be demonstrated. Small test coils will be used to develop power supplies able to sustain the necessary stability.

BNL is engaged in informal discussions with three laboratories about developing specialized superconducting magnets for their facilities: the BEBC electron-positron collider in Beijing, China; the PEP-II electron-positron collider at the Stanford Linear Accelerator Center; and a proposed proton radiography facility at Los Alamos National Laboratory. These projects would involve producing a small number of magnets that would extend the capability of the Magnet Division.

The R&D and the production work in the Superconducting Magnet Division are expected to continue for many years since both fabricating superconducting magnets and magnet R&D are important functions to the long-range accelerator programs at BNL and other institutes, including the operation and improvement of the RHIC facility. In this work, the Superconducting Magnet Division collaborates with the Superconducting Materials Group in the Materials Sciences Department in developing magnets using HTS superconductors.

5.2.2.3 Advanced Instrumentation

Present Program: BNL has strong core competencies in advanced detector-, instrumentation-, and source-development related to our main user facilities and to other DOE facilities.

The Instrumentation Division is a research division that develops state-of-the-art instrumentation for BNL's scientific and technical organizations. The Division provides the research programs with expertise in detectors, microelectronics, micro-fabrication, lasers, and optics. The current focus includes the following technical areas:

- Semiconductor detectors,
- Gas and noble liquid detectors,
- Lasers and optics,
- Monolithic circuits, and
- Micro- and nano-fabrication

The Instrumentation Division also offers specialized shops, laboratories, and development areas. In many of the technical areas, the instrumentation developed at BNL has been first-of-a kind and has enabled the Laboratory's scientific staff and users to pursue experiments that could not have been attempted without it. Examples include liquid argon calorimetry, silicon drift detectors, cathode pad chambers, low noise electronics, and optics metrology. In the foreseeable future, the size and mission of the Division will remain stable to preserve and encourage the continued innovation of instrumentation concepts that look to future capabilities for BNL's scientific and technology applications.

BNL has been a leader in advanced instrumentation for synchrotron sources for over a quarter of a century and many of the techniques for spectroscopy, scattering, and imaging have resulted from the programs both at the NSLS and in BNL's research departments. Recent examples are the applications of circular magnetic dichroism using lock-in techniques centered on an elliptically polarized wiggler that can switch the helicity of the photon beam at rates of up to 100Hz, and on the application of infrared spectromicroscopy. The development of the latter led to the construction of six beamlines at the NSLS making the facility a leading center for characterizing materials using infrared radiation.

In collaboration with the Advanced Photon Source (APS) and the Geophysical Laboratory, we are developing techniques for inelastic scattering at high pressure. The BNL Physics Department is a leading member of the CMC CAT at the APS where BNL staff is involved in developing and using an insertion device beam. An essential role for the Electron Spectroscopy Group is developing new spectroscopic techniques, based at the NSLS, in angle resolved photoemission and infrared spectroscopy to allow detailed studies of correlated systems.

Our current activities also include applying transient frequency modulated spectroscopy to examine the product state distributions of benchmark unimolecular reactions, and the development of ion imaging methods to study the gas-phase products of surface reactions using coherent VUV radiation, such as that available from the proposed DUV-FEL facility.

Future Program: Over the next few years, BNL will continue to support the scientific users at the Laboratory with an emphasis on completing work for the U.S. ATLAS Project and RHIC detectors, as well as various projects for the Medical Research Program, new detectors for protein crystallography, and neutron detectors for the SNS. Several new projects are anticipated that will support the applied science programs, the new fixed-target experiments, MECO and KOPIO at the AGS, as well as R&D on new instrumentation concepts for upgrading the ATLAS detector and the new detector envisioned for the eRHIC facility. Many new efforts will center on improving the electronic systems, especially their radiation hardness. In addition, in the immediate future we intend to upgrade and enhance BNL's capability in nanoscale patterning for basic science studies and for sensor devices.

Brookhaven will continue to make important advances in instrumentation leading to new applications of laser spectroscopy with high temporal and spectral resolution. We will continue our current activities on applying transient frequency modulated spectroscopy and developing ion-imaging methods to study the gas-phase products of surface reactions using coherent VUV radiation. In addition, BNL submitted a new proposal to the DOE's Fourth Generation Light Source Initiative to generate and characterize attosecond pulses.

5.2.3 Condensed Matter Physics, Materials and Engineering Sciences (KC)

The condensed matter and materials science programs at BNL recently concentrated on exploring magnetism and superconductivity, and on studying phase transitions in the bulk materials and at surfaces. In addition, a joint program in the Physics and Materials Science Department is developing a vibrant capability for synthesizing materials in-house, including Pulsed Laser Deposition (PLD) thin film and single crystal oxide growth that eventually will become part of the Nanoscience Center. Much of the experimental work requires instruments developed at Brookhaven's major user facilities and fosters continuing interactions of the facility and BNL staff. There are collaborative projects with other scientists at Brookhaven, at universities, at other national laboratories, and from industry. Some current research themes, which cross discipline boundaries, include the following:

- Strongly correlated and complex systems, especially transition metal oxides,
- Surface and interfacial structure,
- Nanoscience, especially of functional materials,
- Soft matter, and
- Energy utilization.

Researchers are investigating the basic relationships between the microscopic structures and macroscopic properties of advanced superconductors, providing the basic data and defining the fundamental materials science required for their effective practical use. Emphasis is on high temperature superconducting cuprates, including investigations of the physical properties of lattice defects, especially their role in altering superconducting properties, as well as the kinetics of the formation of these oxides in practical conductors. BNL researchers extensively use transmission electron microscopy, neutron diffraction, and x-ray diffraction and spectroscopy techniques at the NSLS. Other researchers focus on developing an understanding of electroresponsive conducting polymers, using this information to synthesize improved materials. Their goal is to elucidate the microscopic origin of the electroresponsive phenomena, such as ionic conductivity, and to develop a rational approach to synthesis. The long-range goal is to fabricate a polymer Li cation conductor with potential applications to real devices. New efforts are concerned with nanoscience including the growth and characterization of functional materials, magnetic composites, and oxide surfaces.

Recent studies include the infrared spectroscopy of calcium copper titanate ($CaCu_3Ti_4O_{12}$) that possesses one of the highest dielectric constants known, the development of theoretical techniques to distinguish evolved and random features in complex networks (such as interacting proteins in yeast), the demonstration that polar nanodomains dampen optical phonons in ferroelectric films, the development of high pressure superhydration techniques in zeolite nanopores to trap radioisotopes, and inelastic scattering studies of the double-mode gap excitation in $La_{2-x}Sr_xCuO_4$.

New programs were started in materials synthesis and in soft condensed matter physics. BNL recruited an expert in oxide single crystal growth, successfully commissioned a new facility for Pulsed Laser Deposition, and hired an Assistant Scientist to focus on nanofabrication and characterization of self-assembled block co-polymer systems. BNL is searching for a third researcher to work on synthesis.

These initiatives involve collaborations that cross BNL's departmental boundaries and are part of BNL's response to the Nanoscience and Complex Materials Initiatives. A significant step was taken to rebuild the Condensed Matter Theory Group by hiring Alexei Tsvelik, a world-renowned theorist as Theory Group Leader, and Fabian Essler, an Associate Physicist. A new search is underway to hire an electronic structure theorist. We submitted NSET proposals on nanomagnetics and soft matter; both involve collaborations among several departments, including NSLS, Materials Science, and Chemistry. A collaborative effort led by the Center for Neutron Science accomplished its near term goals of moving HFBR instrumentation to HFIR, NIST, ANTSO (in Australia) and HANARO (in S. Korea). BNL is establishing a presence at HFIR for constructing a cold triple axis facility, setting up a Science Alliance that involves a BNL scientist who will be located at NIST, and laying out plans designing and building a HYSPEC, an SNS instrument in which BNL will play a leading role. Finally, a concerted effort will be made to form joint appointments between the USB Physics and Materials Science Departments and BNL.

5.2.3.1 Neutron Scattering

Present Program: The principal objective of the neutron scattering program at BNL is to gain an understanding of underlying physical principles involved in cooperative phenomena in complex solids by elastic and inelastic neutron scattering research. This research includes structural and magnetic phase transformations, magnetic structure, and elementary excitations, such as spin waves and phonons. A major theme of our current research concerns strongly correlated electron phenomena in transition-metal-oxide compounds such as high-temperature superconductivity in the layered cuprates and charge-stripe order in nickelates. We are interested particularly in the interplay between electronic, magnetic, and structural degrees of freedom in these systems, and the nanoscale spatial inhomogeneity resulting from competing interactions. Other interests include dimensional cross-over in systems of weakly coupled spin-chains, quantum critical phenomena, the effects of nanodomains in relaxor ferroelectrics, and shape-memory alloys exhibiting Martensitic phase transformations. Neutron scattering is a unique tool for studying these phenomena, and experiments are done at other neutron facilities in the U.S. and abroad. In many cases, this work is complemented by parallel studies using x-ray scattering or electron spectroscopy at the NSLS. These research efforts respond to the DOE's initiatives in Complex Materials and in Nanoscience.

This year, researchers observed the rotation of magnetic stripes from diagonal to parallel in a cuprate superconductor, the first stripe liquid in a layered nickelate, and a soft phonon mode in a relaxor ferroelectric. In addition, a junior level researcher was hired from The University of Chicago to replace Andrey Zheludev.

Future Program: Next year, researchers will continue to study quantum phase transitions in low dimensions, especially spin chains, nanoproperties of ferroelectrics, and the origins of high T_c superconductivity in complex materials. An expert in single crystal oxide growth will develop a new program in this area, starting with $Bi_2Sr_2CaCu_2O_{6+\delta}$, to look for evidence of stripe correlations. Efforts are underway to hire Meigan Aronson from The University of Michigan in a joint BNL-USB appointment to pursue both synthesis and neutron scattering studies. A major long-term initiative will involve developing and constructing a direct-geometry time-of-flight instrument (HYSPEC) for spectroscopy at the Spallation Neutron Source (SNS) in collaboration with BNL's Center for Neutron Science and the SNS. We expect the Experimental Facilities Advisory Committee's (EFAC's) approval of our concept this year; this will be followed by the formation of a larger collaboration with university and other scientists to apply for funding and build the instrument. BNL anticipates participation in the design and construction of still other SNS instruments in the future.

5.2.3.2 X-ray Scattering

Present Program: The central objective of this program is to study the structural, electronic and magnetic properties of condensed matter systems using synchrotron-based scattering techniques. Researchers are particularly interested in investigating surface and interfacial phenomena, including thin films, magnetic structure and phase behavior, orbital and charge ordering in transition metal oxides, and electronic excitations in solids. Much of the work of the Scattering Group is collaborative with researchers at universities, in industry, and from other national laboratories, as well as scientists from other departments at Brookhaven. There is a collaborative focus on the DOE's initiatives in Complex Materials and in Nanoscience. Experiments are carried out primarily at the Group's NSLS and APS beamlines. A significant new development is the submission of NSET proposals on nanomagnetics and nanotemplate directed assembly of soft matter and biomaterials. The latter project, if funded, will be used to spin off a new group in interdisciplinary soft matter studies.

This year, researchers observed a double-mode gap in inelastic scattering studies of $La_{2-x}Sr_xCuO_4$, carried out preliminary studies of nanowetting of thin organic liquid films deposited on nanotemplated substrates, and synthesized giant polyoxomolybdate clusters analogous to the putative C_{240} molecule.

Future Program: Next year, researchers will extend their studies of charge and orbital ordering of thin transition metal oxide films, continue to explore the wetting of nanolandscaped surfaces, search for excitations of orbital waves ("orbitons") in manganites, and investigate the use of polyoxomolybdate clusters as "cages" for magnetic ions to form nanomagnets. These studies (and others) will benefit from the construction of the BNL Nanocenter planned over the next five years. Funding was obtained from the DOE and NSF for the BNL-led Inelastic Scattering Collaborative Access Team (IXS-CAT), permitting beamline construction at the APS. Construction is scheduled for completion by 2005, thereby letting the 16-institution IXS-CAT consortium begin experiments.

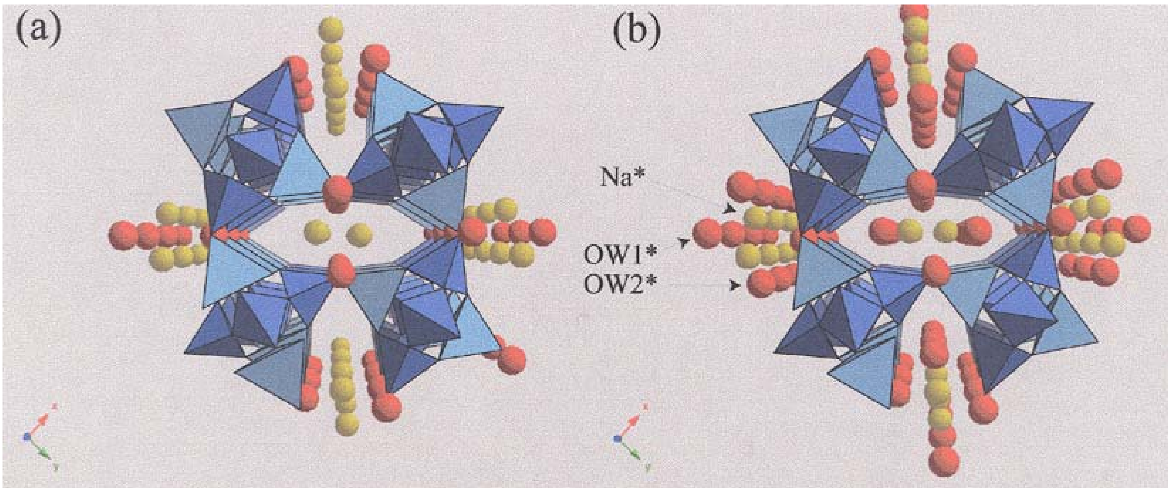
5.2.3.3 Powder Diffraction

Present Program: The focus of this research is to increase the fundamental knowledge of structure-property relationships of inorganic materials and, in particular, of oxides consistent with the DOE's initiative in Complex Materials and Nanoscience. The researchers use synchrotron powder diffraction capabilities at the NSLS and neutron powder diffraction at various national and international neutron sources, to study rare earth doped manganates and cobaltates, metal alloys, and oxides used as battery electrodes, ferroelectric materials of the lead zirconate-titanate system, framework structures, and magnetically ordered alloys and compounds. One goal is to elucidate phase transitions, in particular those involving charge and spin ordering, using Rietveld refinement techniques including *ab initio* solution of the structure of unknown materials. The Powder Diffraction Group also is the steward of the X7A beam line at the NSLS in conjunction with a Participating Research Team comprised of four industrial members and six academic institutions. BNL maintains a small synthesis effort for systematic studies of stoichiometry and compositional fluctuations, in collaboration with the work on oxide growth underway in the Neutron Scattering Group.

This year, the researchers carried out the first high pressure crystallographic studies of superhydrated zeolite (Figure 9) and showed how these techniques may be used to trap radioisotopes. They also discovered two distinct structural phase transitions in $TbBaFe_2O_5$ and showed that the monoclinic phase originally found in lead zirconate titanate (PZT) is common to a range of piezoelectric materials, thereby suggesting a common origin for the large piezoelectric effect.

Future Program: BNL's pioneering work in the superhydration of zeolites will be expanded into other areas, e.g., toward pyroclores and perovskites. Efforts will be made to enter the area of functional oxide heterostructures using BNL's PLD capability, while pair-distribution-function techniques will be developed to analyze crystallographic data obtained from nanosystems. A consortium is forming under the auspices of the NSLS to upgrade and operate X7A and two other beamlines specialized for powder diffraction. At the same time, a search is underway for a chemist/physicist at the Assistant Scientist level to initiate an independent program in materials synthesis that complements and extends the present efforts in PLD and oxide single crystal growth elsewhere in Condensed Matter Physics. In the long term, we anticipate that the focus of the powder diffraction group will evolve toward synthesis and characterization, and that it eventually will play a significant role in the BNL Nanocenter.

Figure 9 - Hydrated Zeolite Natrolite and Its Superhydrated Structure Above 1.5GPa
The hydrated zeolite is shown in figure (a) while the superhydrated structure is shown in (b).



5.2.3.4 Electron Spectroscopy

Present Program: In the Electron Spectroscopy Program, researchers study the electronic and magnetic properties of surfaces and thin films, and examine how they influence the physical behavior of materials. Research includes the following:

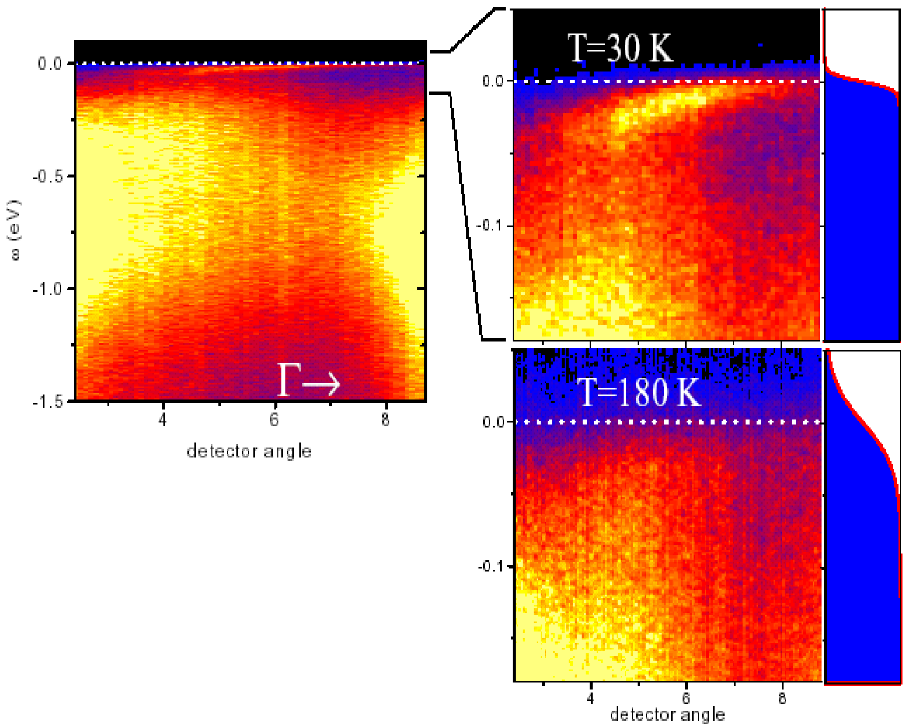
- High resolution photoemission studies (HPES) of complex oxides,
- High resolution studies of the metal/insulator transition in ultra-thin films,
- Infrared studies of correlated metals including ultra-thin films and oxides, and
- Spin-polarized valence-band and core-level photoemission studies of magnetic films and multilayers.

This research supports the objectives of the DOE and Nanoscience Initiatives.

This year, researchers carried out high-resolution photoemission studies (Figure 10) to explore the correlation between effective dimensionality in cuprate superconductors and the character of their excitation spectrum, to characterize the infrared spectrum of calcium copper titanate, and to characterize the optical and electronic properties of MgB_2. The Pulsed Laser Deposition (PLD) facility was commissioned and a range of thin films grown, including the high dielectric constant material calcium copper titanate, $NdNiO_3$, $LaCuO_4$, and $LaNiO_4$.

Future Program: High-resolution photoemission studies will continue of other two-dimensional charge-density-wave systems and high T_c materials. The current project involving HPES studies of doped C_{60} molecules will be extended to carbon nanotubes, as part of BNL's program in nanoscience. Work on the optical properties of ultra-thin metallic films will proceed, emphasizing the adsorption of organic and insulating layers. In the longer term, the PLD facility will be upgraded to include laser assisted molecular beam epitaxial (MBE) growth, together with *in situ* photoemission studies. Experiments will explore the possibility of using time-dependent photoemission studies to learn more about quasi-particle self-energies. A new facility for infrared studies of materials under pressure will be established.

Figure 10 – The High Temperature Photoemission Spectrum from $(Bi_{1-x}Pb_x)_2M_3Co_2O_y$.
At high temperatures (180K) the photoemission spectrum from the strongly correlated material $(Bi_{1-x}Pb_x)_2$ $M_3Co_2O_y$ shows only incoherent emission. At low temperatures (30K), sharp electron-like excitations exist just below the Fermi level.



5.2.3.5 Condensed Matter Theory

Present Program: BNL's condensed matter theory group works in close collaboration with the neutron scattering group on magnetism and high temperature superconductivity. A program to understand charge transport in "bad metals", such as oxide and organic conductors and superconductors, is an on-going collaboration with the experimental group that is working on infrared and angle-resolved photoemission spectroscopies. Theoretical studies on magnetic scattering and orbital ordering impact strongly on the research of the Scattering Group. All this research responds to the objectives of the DOE's initiatives in Complex Materials, Nanoscience, and Scientific Computing. Theorists address different aspects of the electronic structure of surfaces and alloys including predicting metastable alloy phases, the magnetism of adlayers and compounds, and the relationships between photoemission spectroscopy and the underlying ground state properties.

During the past year, researchers developed theoretical techniques to distinguish evolved and random features in a complex network, such as interacting proteins in yeast, developed a non-perturbative description of the Mott-insulator metal transition for weakly coupled chains, and calculated the dependence of the lattice constant on crystallite size for $BaTiO_3$ nanocrystals, as determined by powder diffraction measurements.

Future Program: Researchers will use non-perturbative techniques to study spin transport in nanowires and quantum dots, investigate the formation of antiphase domain walls in doped antiferromagnets, explore experimentally determined optical conductivities of “bad metals” using approaches beyond the Fermi liquid theory, carry out first principles studies of the electronic and magnetic properties of complex materials including bulk and nanopatterned thin films of transition metal oxides, and develop statistical methods with applications in economics, biology, and soft matter. A longer-term goal is to establish an Institute for the Study of Correlated Systems to serve as a worldwide focal point in correlated electron studies. The Institute will host short and long-term visitors, arrange workshops, and organize coherent approaches to outstanding problems, thereby establishing BNL as a leader in the coming revolution in this area.

5.2.3.6 Materials Chemistry and Electrochemical Sciences

Present Program: Materials chemistry research involves the synthesis and structure of conducting polymers, and electrochemical research involves studies of the mechanisms of metal-environment interactions.

The Conducting Polymer Group applies an interdisciplinary approach to the synthesis and characterization of ion conducting polymers. Their goal is to design and synthesize new functional groups and new ionic conducting polymers based on studies of ion-ion and ion-polymer interactions in non-aqueous electrolytes. Absorption and Raman spectroscopy studies indicate that ion pairing and cluster formation occur in non-aqueous electrolytes. All conventional non-aqueous electrolyte solvents, including poly (ethylene oxide), are Lewis bases that interact strongly with cations. BNL’s new approach is to modify the solvent chemistry to enhance anion-solvent interactions by adding to the solvent new Lewis acid compounds synthesized at BNL. The compounds form complexes with the anions, dissociate the ion pairs, and free the cations. Therefore, the number of charge carriers, the conductivity, and the Li^+ ion transference number all increase significantly. Researchers use electrochemical and conductivity studies and a wide array of spectroscopic techniques, such as x-ray absorption spectroscopy (XAS), to elucidate ion-ion and ion-solvent interactions.

The Mechanisms of Metal-Environment Interactions group studies beneficial and destructive reactions that take place on surfaces of metal resulting in the formation of protective coatings or products of corrosion, respectively. The program focuses on the processes by which these reactions take place and characterizes the physics and chemistry of the products, and their dependence on the metallurgical nature of the metal or alloy taking part in the reactions. The research direction emphasizes *in situ* methods and takes advantage of the facilities at BNL to conduct this innovative research, such as synchrotron and infrared photon beams and transmission electron microscopy.

Future Program: Future work in the Conducting Polymer program is outlined below:

- The design, synthesis, and characterization of polymer and gelled electrolytes with Lewis acid centers. The emphasis will be on cation conducting polymers with conductivities $>10^{-4}$ S/cm at 25°C.
- Raman studies of polymer electrolytes.
- The development of functional nanomaterials, for batteries and fuel cells, in collaboration with SUNY Stony Brook
- The study of the oxide layers formed in organic media.
- The study of localized corrosion of active metals, including aluminum and magnesium.
- The chemical and physical properties of oxide films formed on transition metal surfaces.

5.2.3.7 Superconductivity and Magnetic Materials

Elucidation of the physical and chemical factors underlying the structure-sensitive properties of superconductors and advanced magnetic materials is key to successfully implementing them in high-efficiency power distribution systems and energy-efficient motors, actuators, and sensors. Major efforts in the Materials Science Department emphasize investigating the properties of superconducting oxides with high critical temperatures and of high energy-product advanced permanent magnets, methods of characterizing and fabricating superconductors and magnets, as well as exploring new materials. The primary goal of these programs is to understand the nanoscopic, microscopic, and microstructural factors influencing the properties of the materials.

Present Program: In this program researchers elucidate factors affecting the structure-sensitive properties of advanced permanent magnet materials and advanced superconductors that are relevant to energy-related technological applications. The research features both experimental and theoretical investigations. The goal is to provide basic data, and to understand the fundamental materials science required for the practical use of these functional materials.

In superconductivity research, we emphasize basic studies of high-temperature superconducting cuprates, particularly $YBa_2Cu_3O_7$ (YBCO) and the recently discovered compound MgB_2. For example, we probe ac loss, critical currents in wide temperature ranges using different cryogens, and use electron beam evaporation systems, and transmission electron microscopy (TEM). Another facet of the superconductivity work is developing suitable conductors for applications of high T_c superconductors for electric utilities, e.g., electric power transmission lines, transformers, and motors. The work includes investigating physical properties and lattice defects, especially their role in altering superconducting properties, as well as studing the kinetics of formation of these superconductors in practical conductors. Studies of thick-film YBCO fabrication are done primarily with BNL's fabrication and characterization facilities. We have on-going collaborations with other laboratories and industries for investigating other YBCO fabrication methods, such as a sol gel process (Sandia National Laboratory), and for obtaining the required buffered substrates (Oxford Superconducting Technology, MicroCoating Technologies, and Argonne National Laboratory). We use TEM and diffraction techniques at the National Synchrotron Light Source. Recent experimental accomplishments in superconductivity include the following:

- Fabrication of fine-grained and fully-connected bulk MgB_2 with a critical current density J_c of ~ 1 MA/cm^2 at 5 K, the highest critical current density ever achieved in the bulk form.
- Clarification of the nucleation process for *c*- and *a*-axis oriented YBCO occurring in the BaF_2 process by using advanced TEM techniques.
- Development of systematic theoretical studies to understand chemical bonding, crystal lattice defects, and the physical properties of the family of rare-earth cuprates; theoretical models of doping, charge, and stress at dislocations and grain boundaries in these materials.
- Development of commercially viable methods of fabricating thick YBCO films on textured substrates.
- Testing high-T_c conductors to determine critical current densities and ac losses under specific conditions (current, ac frequency, applied magnetic field, temperature) for applications for motors, transformers, and power transmission cables.

The objective of our advanced magnetic materials research is to understand and manipulate materials factors that control their collective magnetic responses relevant to their energy-related technological applications. Our research focuses on nanostructured rare earth – transition-metal-based magnetic (RE/TM) intermetallic compounds, such as $Nd_2Fe_{14}B$ and $PrCo_5$. As part of this research we also study model systems of nanocomposite materials such as thin-film bilayers of CoPt-Co, and develop a many-atom potential model of cohesion and magnetic order in RE/TM-based compounds. The advanced magnetic materials research features both theory and experiment, and uses the facilities at the NSLS and the APS. Other experimental probes include advanced SQUID microscopy, atomic and magnetic force microscopies, thermal analyses and TEM. Our collaborators include researchers from the Idaho National Engineering and Environmental Laboratory, Magnequench International, Inc., Ames Laboratory, Lehigh University, and Carnegie Mellon University. The scope of the research is expanding to include basic studies of related magnetic alloys and precursors in their nanocrystalline and/or amorphous forms, such as amorphous Nd-Fe-B and the "bulk amorphous" alloy $RE_{60}Fe_{30}Al_{10}$, where RE is a rare-earth component, such as Nd or Pr. The following are some recent experimental accomplishments in research on advanced magnetic materials:

- Identified the role of atomic clustering in the solidification, crystallization behavior of rapidly solidified $Nd_2Fe_{14}B$;
- Developed processing principles to control microstructures in composite magnets, thereby improving their technical magnetic properties;
- Developed a model predicting the magnetization behavior in permanent magnet materials based on competition between the domain wall pinning and nucleation;
- Correlated the degree of thermo-mechanical deformation with magnetization reversal and induced collective behavior in melt-quenched $Nd_2Fe_{14}B$-based materials;
- Quantified the strain state in $Nd_2Fe_{14}B$-α-Fe nanocomposites by analyzing the diffraction peak broadening, and delineated the relation of inherent strain to the magnetic properties.

Future Program: We will pursue a deeper clarification of the nanostructure of the superconducting and advanced magnetic materials. We will complete development of electron holography techniques to investigate mechanisms of the effects of grain boundary misorientations on J_c in $Bi_2Sr_2Ca_2Cu_3O_x$ and YBCO and, and develop theoretical models to describe the interaction of crystal lattice defects with electronic stripe structure formation in cuprate superconductors, as well as determining defect-superconductivity interactions in MgB_2. In the applied arena, the fabrication methods developed for cuprates will be used to generate nanoscale structures of other transition-metal oxides to study their size-dependent structure and properties. Future research directions in the field of advanced permanent magnets include understanding the role of the matrix, and the shape of nucleated grains in mediating interparticulate interactions in ferromagnetic nanocomposites, and clarifying the role of interfacial quality on exchange coupling and reversal behavior in CoPt/Co model bilayers and related materials. Finally, we will continue to investigate the influence of melt-quenching conditions on the microstructure and magnetic domain structure in advanced magnetic alloys.

5.2.3.8 Advanced Electron Microscopy Study of Nanostructured Materials

Present Program: The goal of this program is to investigate property sensitive structural defects in technologically important materials, such as superconductors, magnets, and other functional materials at the nanoscale. Advanced quantitative electron microscopy techniques, such as coherent diffraction, atomic imaging, spectroscopy, and phase retrieval methods, including electron holography are developed and employed to study material behaviors. Computer simulations and theoretical modeling aid in interpreting experimental data. Our research also incorporates the fabrication of thin films with tailored microstructure and nanoassemblies using TEM based electron lithography to understand the materials' electronic and magnetic behaviors. Recent progress includes the following:

- Understanding structural defects and charge distribution and hole symmetry near the Fermi level of the newly discovered MgB_2 superconductor,
- Developing a unique symmetrization method based on the transport-of-intensity equation for nanoscale magnetization mapping of various magnetic materials,
- Developing quantitative algorithms and procedures for measuring interfacial potential using electron holography to study charge distribution across Bi-2212 and Ca-doped YBCO superconductor grain boundaries,
- Fabricating Co nanoparticles via *in situ* TEM manipulation of CoF_2 films and their formation mechanism.

Future Program: The future program will include fabricating nanomagnetic-arrays to study magnetic structure and properties, including exchange coupling and switching behavior as a function of particle size, shape, and magnetic field; quantitative studies of magnetic potential distribution using phase retrieval methods and comparing experiments with theory; quantitative studies of interfacial electrostatic potential using electron holography and nanoprobe energy loss near edge structure (ELNES); and, applying advanced microscopy techniques to tackle fundamental issues of condensed matter physics and materials science in nanoscale materials.

5.2.3.9 Program Initiatives

Center for Neutron Science: This initiative will develop a comprehensive neutron research program to sustain BNL’s world-class neutron science capabilities, and continue to support the major investment in neutron facilities and research at other DOE facilities. Currently, BNL’s neutron scientists conduct their research at the NIST reactor and ISIS. BNL's Center for Neutron Science will evolve a new neutron program that involves the following components:

- Develop a test facility beamline at the AGS for research and development to support spallation neutron instrumentation and components, focused on the SNS. For example, there are several experiments involving international collaborations using the record proton per pulse intensity from the AGS to study shielding and moderator issues.
- Develop state-of-the-art instruments for neutron sources in the U.S., primarily for the SNS. These efforts encompass all aspects, including commissioning and operations. We will provide forefront experimental capabilities for the national program using neutrons from both pulsed and steady state sources. Possible instruments include a high-resolution backscattering crystal spectrometer and a hybrid spectrometer for the SNS, and a triple axis spectrometer optimized for cold neutrons produced at HFIR.
- Develop novel detectors for neutron applications. This is a joint effort with BNL's Instrumentation Division to provide large area detectors with good spatial resolution and excellent temporal resolution. These efforts will directly support instrument development at both BNL and in the neutron community for the SNS.
- Define and implement future research directions for neutron science. Forefront areas of research involve understanding increasingly complex systems where the variations and interplay of the electronic, magnetic, chemical, and mechanical properties must be known so that they can be manipulated at the nanometer length scale. Such systems include correlated-electron systems, new nanocatalytic materials, hydrogen storage, micro- and macro-porous materials, and block copolymers. Neutron-scattering techniques are universally accepted as a critical tool for revealing the structural properties of matter on this scale, and have the unique ability to probe dynamic response that many believe will play a decisive role in the evolution of nanotechnology and catalytic materials.

- Develop a regional education and training program based at BNL for training graduate students and postdoctoral researchers who will interact with BNL's scientists for neutron-science measurements and instrumentation design.

- Undertake initial studies for a Continuous Spallation Neutron Source (CSNS) to accommodate the DOE-BES roadmap for Major Facilities, which states that a new steady state neutron source will be needed by 2008. This facility will be based upon a high power superconducting linac and a heavy metal target that could be constructed at BNL. The goal is to investigate the feasibility of a new accelerator-based neutron source. The timing of building this facility must be planned in concert with the DOE Office of Science.

The Laboratory's near term goals are (1) to develop, with DOE BES, an agreed-upon plan for Neutron Science at BNL, (2) to continue joint international experiments on the effectiveness of neutron shielding at the BNL neutron test facility with colleagues at JAERI, (3) to present to the Instrument Oversight Committee (IOC), in collaboration with the national SNS project, a proposal for two neutron instruments, and (4) to develop closer working relationships with HFIR and NIST. Our long-term goal is to reinforce and maintain a vigorous neutron science and instrumentation program at BNL.

Materials Science Revitalization: BNL took several actions to integrate more closely the programs in materials physics, metallurgy, and materials chemistry with those in condensed matter physics and several areas of chemistry. Our goal is to strengthen traditional core programs and compete more effectively with interdisciplinary responses to the DOE's initiatives. A new Materials Sciences Department (MSD) was formed within the Basic Energy Sciences Directorate with David Welch as the Interim Department Chair. In addition, the programs in Materials Science were united with those in Condensed Matter Physics by establishing a Materials Center. The Center, headed by Doon Gibbs, coordinates internal programs in materials science at the NSLS, the new Materials Science Department, the Condensed Matter Physics Section of the Physics Department, and the Chemistry Department. This effort has given Center members better access to all the experimental resources on the site and opportunities for collaboration through joint seminars and research initiatives. There are now strong partnerships between BNL's Condensed Matter Physics programs and the MSD, i.e., work on high T_c superconductivity and the new superconductor MgB_2 and in various areas of nanoscience, such as nanoscale magnets, correlated electron systems, and transition metal oxides. An increase in these intra-laboratory collaborations is a very high priority, especially in areas involving synthesis and processing, as well as the characterization of nanoscale structures by TEM in a wider range of functional materials, and in materials theory; it will be facilitated by this new management structure. The MSD is expected to play a critical role in the BNL Nanocenter. A joint effort planned between the Center for Data Intensive Computing and MSD will strengthen our capability in the theory, modeling, and simulation of advanced materials.

Future directions and strategic plans for materials science are as follows:

- Focus on understanding defects and the "real structure" of nanomaterials, in particular, on the properties of metal oxides.
- Expand the TEM program, emphasizing nanophenomena and structures, and the roles of defects in them.
- Expand efforts to synthesize and process metal-oxide nanoparticles and nanocomposites at both BNL and with our collaborating universities.
- Incorporate a strong program in *ab initio* calculations in conjunction with other methods of modeling.
- Increase the emphasis on non-superconducting functional materials, such as ferroelectrics,

piezoelectrics, and magnetoresistives.

The strategy for implementing and strengthening these new directions has several features. A major one is even stronger interactions between the MSD, Condensed Matter Physics, and the Center of Data Intensive Computing. Other aspects include appointing key senior personnel and increasing the number of joint appointments with the State University at Stony Brook.

5.2.4 Energy Sciences (KC)

BNL's Energy Science R&D emphasizes energy conversion, energy use, and alternate sources of energy. This research is coupled to our competencies in advanced experimental techniques, such as neutron and x-ray scattering, and on our unique facilities and capabilities; it concentrates on basic research in combustion, catalysis, biofuels, batteries, and solar energy conversion. The Basic Energy Science Program Offices sponsor this research. Other offices within the DOE programs sponsor work related to the DOE's Energy Resource Mission area. These are summarized in Section 5.3.

BNL's basic energy science research broadly encompasses catalysis, combustion, and radiation-induced chemistry for energy conversion and storage, and plant biosynthesis. The new Laser Electron Accelerator Facility (LEAF) provides a one of a kind tool for investigating the temporal properties of electron transfer associated with chemical, solar, and electrochemical energy conversion. New experimental tools for investigating the rates of gas-phase radical chemical reactions, and the nucleation and growth of aerosol particles help elucidate the efficiency of fossil fuel combustion. Plant sciences encompass mechanistic and molecular based studies of photosynthesis, lipid metabolism, and genetic systems. The studies on lipid biosynthesis may lead to exciting prospects for engineering new pathways for synthesizing alternative fuels and petroleum replacing chemicals.

5.2.4.1 Catalysis and Interfacial Chemistry

Present Program: The primary goal of the Catalysis and Surface Chemistry research is to understand at the molecular level, the chemical reactions that take place at the surface/interface of solids. This knowledge can be achieved only by examining how chemical reactivity responds to the interplay of the physical and electronic structure, morphology, and the dynamic properties of a material. BNL's current research includes the fundamental aspects of sulfur interaction with model catalysts, the synthesis and reactivity of doped metal oxide powders, the preparation, characterization, and reactivity of nanoparticles, the selective oxidation of small hydrocarbons, and the dynamics of desorption and activated adsorption. By combining spectroscopic techniques (e.g., photoemission, XAS, state-resolved laser ionization) with structural tools that probe short and long-range order, BNL's scientists can identify and characterize reactive surface species over a wide range of time and length scales and under a variety of conditions, including high pressure and temperature. Many measurements make extensive use of synchrotron radiation from the NSLS at two beam lines supported by the Chemistry Department (X7B, U7A).

The goal of research in electrochemical/electrocatalysis is to understand the relationship between the structure of an electrode surface and its electrocatalytic properties, and the role of phase formation in the stability of intercalation electrodes. In addition, our results will have potential applicability in electrochemical energy conversion in fuel cells and lithium batteries.

Near-term Program: Recent studies using atomically resolved Scanning Tunneling Microscopy (STM) demonstrate that atomic-scale imaging will enhance significantly our understanding of metal-on-metal growth, morphology, and reactivity in two-dimensional reactions on surfaces. The Ultra-High-Vacuum (UHV) STM instrument is a nanoscale probe for surface structure of model metal catalysts whose reactivity is probed by a high-resolution photoemission instrument at the NSLS U7A beam line. This work emphasizes metal-on-metal and metal-cluster on oxide growth. Our goal is to control the dispersion and density of clusters, and to understand the parameters controlling the stability of their morphology. A new molecular beam scattering apparatus that can provide information about barriers and the role of internal energy in activated gas-surface reactions, and can bridge the high-pressure and UHV reactivity studies, will complement reactivity studies of model metal catalysts and nanoparticles.

Future Program: In the future, the program will focus on the reactivity and structure correlations of nanoscale materials that hold considerable promise as chemical- and photo-catalysts with properties that can be controlled by particle size, particle density, and chemical environment. To be successful, we need new expertise in materials synthesis, as well as to develop characterization tools that can index chemical activity with the spatial resolution of proximity probes, such as near-field optical IR and UV spectromicroscopy. A novel synchrotron-based instrumentation using LEEM/PEEM/XPEEM (Low Energy Electron Microscope, PhotoEmission Electron Microscope, X-ray PhotoEmission Electron Microscope) holds great promise for catalysis science because it will probe the structure and reactivity of surfaces in the sub-second time domain and at the submicron scale. High pressure synchrotron-based soft xray photoelectron spectroscopy (XPS) will help close the existing "pressure gap" between catalysis and surface science, and provide new insights into the fundamental details of surface catalytic reactions under realistic conditions (~10 torr).

5.2.4.2 Photo- and Radiation-Induced Chemistry

Present Program: In this program we apply the complementary techniques of excitation by photons or fast electrons to understand the basis of capturing and storing light energy in useful chemical forms. We investigate electron transfer reactions, motions of charges in condensed media (including glasses and supercritical fluids), dipole-moment changes in charge transfer transitions, formation of excited states of molecules, transition metal complexes, radicals and radical ions, and chemical and physical transformations of excited and highly reactive species. LEAF adds a new dimension to our capabilities for these studies. We are carrying out theoretical and experimental research in a wide range of donor/acceptor systems, elucidating the factors that control excited-state lifetimes and electron transfer rates, the roles of nuclear-configuration and free-energy changes, electronic configuration, orbital symmetry, donor/acceptor separation, bridging groups and solvent dynamics. The long-term storage of solar energy as fuels or valuable chemicals requires efficient coupling of light absorption and chemical transformations. One major effort centers on mechanistic studies of systems which couple photo-induced electron-transfer processes to the bond-forming reactions required in the photogeneration of dihydrogen and the photoreduction of carbon dioxide to carbon monoxide or methanol. Kinetic and mechanistic studies of transition metal hydride complexes are designed to understand the factors governing the rates and mechanisms of M-H bond cleavage; the knowledge gained guides the development of new homogeneously catalyzed reactions. In addition, conformationally designed synthetic porphyrins are characterized and the consequences of the skeletal distortions observed *in vivo* are documented. These compounds are new classes of biomimetic chromophores and catalysts with tunable and controllable photophysical and chemical properties.

Future Program: Through experiments coupled to theory, we will investigate chemical systems for long-term storage of solar energy, as well as photo- and radiation-induced charge injection and transport in nanoscale materials. Experiments at LEAF will characterize ion recombination reactions and probe the unusual species formed when supercritical fluids are ionized. The lifetimes of excited ions that could function as energy-storage intermediates will be measured for the first time to ~0.1 ps. The nature of "dry-electron" capture will be probed and a search launched for unstable ions of metal hydrides that might be intermediates in reactions catalyzed by these species. The search will continue for methods to photoreduce energy-poor substances (carbon dioxide to carbon monoxide or methanol). We will investigate catalysis for energy storage by metal complexes and metal macrocycles using transient optical absorption, transient FTIR, and a variety of structural techniques at the NSLS. Using electroabsorption spectroscopy, we will elucidate charge transfer events in metal complexes and dyes adsorbed on nanoparticles. Our focus is shifting increasingly to nanoscale materials and processes, and we will begin studies of electron and photon injection into metal nanoparticles, molecular wires up to 50 nm long, and nanotube assemblies. We also will explore applying designer porphyrins as molecular wires or photonic devices, biomimetic catalysts, light-harvesting arrays, and for artificial photosynthesis.

5.2.4.3 Gas-Phase Reaction Dynamics and Combustion

Present Program: Accurate models of combustion chemistry in real systems require accurate kinetic data for radical-radical reactions over a wide range of temperature and pressure. At Brookhaven, these measurements are made by a combination of high-resolution, high-sensitivity, laser absorption methods and by high-temperature, flow-tube reaction kinetics studies with mass-spectrometric sampling. Spectroscopic measurements and theory of radical species, such as CH_2, C_2H_5, HOCO, and C_2Br, provide information on the energy levels and structures and, in turn, provide new tools for studying energy flow and chemical bond cleavage in radicals involved in chemical reactions. Experimental and theoretical studies of reaction dynamics address more detailed questions about such reactions than can be answered through kinetics studies. Recent kinetic studies focused on the CH_3 + O radical-radical reaction for which the carbon monoxide (CO) product fraction was accurately determined via mass spectrometry, isotope labeling, and diode-laser adsorption spectroscopy.

Future Program: This research will extend to other crucial radical-radical reactions, such as two of the poorly understood reactions of the propargyl (C_3H_3) radical that are thought to play a crucial role in initial stages of soot formation in hydrocarbon combustion. This work bears on both the efficiency of fossil fuel combustion and its environmental impact, and will form the basis of future efforts in gas-phase radical chemistry, including new developments in reaction dynamics. With a highly interactive collaboration that combines experimental and theoretical approaches or a combination of experimental techniques, BNL's research will expand to investigate the spectroscopy and electronic properties of radicals and metal-containing clusters, fundamental studies of the dynamics, energetics, and reactivity of polyatomic radicals and highly excited molecules, and elucidate the rate constant and product yields of the radical-radical reaction CH_3 + OH. The methylene generated in this reaction leads to the formation of the CH radical that reacts with nitrogen to form nitrogen-containing combustion products. A new program on experimental and theoretical studies of the electronic structure of metal-containing cluster compounds cuts across programs in gas phase chemical dynamics, surface chemistry, and catalysis. The gas phase radical chemistry program is a joint effort between BNL and the Chemistry Department at Stony Brook University to investigate the dynamics of radical reactions using novel ion-imaging and intense VUV radiation from BNL's DUV-FEL.

5.2.4.4 Bioenergetics Research

Plants represent vital sources of food and materials for society. They convert light to chemical energy and help maintain atmospheric carbon dioxide balance. They have been bred for thousands of years for specific desired traits. For some traits, conventional plant breeding, while still an indispensable tool, is close to reaching practical limits because natural genetic variation can no longer be exploited. New genetic material can be supplied by systematically understanding the fundamental processes underlying agronomic traits.

Present Program: BNL's plant program uses the most advanced biochemical-genetic techniques to develop a conceptual framework for understanding the factors that contribute to the complexity of plant traits. In the short term, we are doing basic research on plant traits and on developing analytical tools to aid breeding. Our long-term goal is to understand specific plant processes in sufficient detail so that scientists can rationally and systematically improve crop plants in various ways. For example, by understanding how plants synthesize fatty acids, their genes can be modified to produce oils with desired properties that can be transferred to crop plants. A major goal of our research is to understand the principles that lead to the accumulation of specific plant products that are of great agricultural importance (e.g., plant oils and cotton fiber). Additionally, we are developing better methods to map and identify genes that affect plant traits.

Research in bioenergetic systems also comprises artificial photosynthesis, plant biosynthesis, lipid metabolism, and genetics. The goal of these programs is to understand how natural plant systems convert energy, regulate the energy conversion process, modify their basic biochemical processes, and may be changed to produce renewable energy resources.

In the past year, researchers used an integrated approach, combining crystallography, spectroscopy, molecular genetics, and biochemistry, to probe structure-function relationships that set the stage for elucidating the specific details of how lipid-metabolizing enzymes work, a necessary step in tailoring enzymes to produce renewable oils for industrial applications. Other specific advancements include the microarray analysis and validation of cotton fiber-specific genes by the quantitative polymerase chain reaction, continued definition of the maize genetic map, and development of a novel strategy for the directed evolution of enzymes.

Future Program: The following are the anticipated long-term advances from the present lines of research:

- Provide a context for generally improving corn and cotton crops by understanding their genome structure and mapping the quantitative trait loci for agronomic and model traits.
- Develop a common context to redesign lipid modification enzymes to enable the introduction at will of chiral chemical modifications along the acyl chain to produce feedstocks that will serve as alternates to currently used fossil reserves.
- Develop plants that can respond better to changes in the quality of light without sustaining damage, a trait that may improve the productivity of crops in existing locations, and expand the range of existing crops to improve productivity per land area.

The genome Arabidopsis, a model broad-leaf plant, was completely sequenced, and about two-thirds of the map-based sequence of the rice genome submitted to public databases; the completion of a high quality draft sequence is envisioned by the end of 2002. Rice, as well as being a very important crop plant, is a model plant for the cereal grasses; one of our researchers is helping to coordinate an international effort to sequence the rice genome. Genome sequences provide a means of rapidly identifying genes that underlie traits, and enable the use of global methods for understanding gene function and regulation. BNL will seek to expand and renew its capabilities in molecular plant genetics and research into fundamental mechanisms that will contribute to faster and better ways to engineer plants with desired properties. These programs will support national and world needs to develop renewal methods for producing raw materials and to meet the DOE's goals in carbon management and bioremediation.

The DOE's Genomes to Life Initiative also may allow BNL to expand its capability for engineering specific traits beyond those available from natural sources by developing a program in directed evolution of proteins and enzymes. The impact of such a program would be to expand our ability to engineer specific traits, and eventually, pathways into plants and other organisms of interest to the DOE.

5.2.4.5 Electrochemistry and Electrocatalysis

Present Program: The primary goal of the research in electrochemistry and electrocatalysis is to understand the relationship between the physical and electronic structure of an electrode surface and its electrochemical and electrocatalytic properties on an atomic level. This work includes studying structure, ordering, surface interactions, and phase behavior of metals, anions, molecular and mixed monolayers on electrode surfaces to obtain a true microscopic description of electrochemical interfaces. Researchers seek basic information on adsorption processes and electrocatalytic reactions at electrochemical interfaces by investigating structural and electronic properties, and structure–activity relationships for these systems. In addition to providing insights into fundamental surface electrochemistry and electrocatalysis, the results will enhance our understanding of the properties of important catalytic materials and provide guidelines for improving and synthesizing new ones. They also have potential applicability in electrochemical energy conversion in fuel cells and lithium batteries.

Our current research focuses on structural and spectroscopic characterization on Pt surfaces with mixed metal-anion, and anion-CO adlayers, time-resolved structural studies of metal monolayer formation and ordering on foreign substrates, and structural characterization of oxide formation on catalytically important metal electrodes. Researchers developed a special spectroelectrochemical "drop cell" that permits *in situ* structural studies without the mass transport limitations of thin layer cells. The techniques permit *in situ* determination of the structure and processes with sub-angstrom resolution and molecular specificity. These techniques include a combination of *in situ* synchrotron radiation based surface scattering and absorption spectroscopy, scanning tunneling microscopy, Fourier transform infrared spectroscopy, and electrochemical spectroscopy.

Future Program: Future efforts will be devoted to structural and catalytic studies of bimetallic single crystal electrode surfaces with monolayer-to-multilayer metal films, or two-dimensional clusters that will be extended to reactivity and structure correlations of nanoscale materials. Our methods of spontaneous deposition of noble metal on noble metal and induced layer-by-layer growth of thin films of catalytic metals will be used to form bimetallic surfaces and for "fine tuning" electronic and catalytic properties. Researchers will identify active sites and study the synthesis of active atomic ensembles for oxygen reduction and oxidation of H_2, CO, and methanol. We will continue structural measurements during electrocatalytic reactions at the electrode, to directly determine the structure-activity correlation, focusing on O_2 reduction, and H_2, CO, and methanol oxidation. The mechanism of oxygen activation during CO oxidation on these surfaces also will be investigated.

Spontaneous deposition of noble metals and induced layer-by-layer growth facilitate a new approach to nanoparticle engineering for synthesizing electrocatalysts. A core nanoparticle is used as a reducing agent for depositing a sub-monolayer shell of catalytic metal for synthesizing novel electrocatalysts with desired properties. This atomic-level design of fuel cell electrocatalysts holds considerable promise for producing active catalysts with low loadings of noble metals.

5.2.5 Environmental Sciences (KP and KC)

Present Program: The DOE's Office of Biological and Environmental Research and the Office of Basic Energy Sciences support BNL's environmental science programs, the centerpiece of which is Climate Change. BNL and partner national laboratories can assist the DOE in implementing the President's Climate Change Initiative. BNL's environmental remediation science and technology programs are aligned with the DOE's focus to implement environmental cleanup faster and cheaper.

The OBER sponsored Atmospheric Science program acquires data to understand the atmospheric processes that control the transport, transformation, and fate of energy-related chemicals and particulate matter. The emphasis is on processes and models related to new air quality standards for tropospheric ozone and particulate matter, and the relationships between air quality and climate change. BNL also is a partner in the DOE-OBER's Atmospheric Radiation Measurement (ARM) program comparing the results of modeled and measured short-wave forcing on tropospheric aerosols and examining the sensitivity of modeled aerosol forcing to input parameters. Collaborating with modelers, we are incorporating humidity-dependent effective radius treatment of aerosol forcing into general circulation models. We also maintain the ARM External Data Center that assembles and distributes data to both the ARM and the broader atmospheric science communities. In another partnership, BNL participates in the DOE-OBER's Water Cycle Pilot Program to investigate the hydrologic cycle, a specific objective of which is to estimate precipitation in the Walnut River, Oklahoma's watershed using measurements from cloud radars.

Our atmospheric science and chemistry research includes the following goals:

- Develop methods and practical instruments for detecting and measuring in real time a variety of atmospheric constituents,
- Develop and apply gaseous tracers to study atmospheric transport and dispersion, building air infiltration and ventilation, the geophysics of oil and gas recovery from production wells, and detection of leaks in fluid handling systems,
- Understand the formation and behavior of aerosols using theoretical, experimental, and field studies,
- Understand the formation, transport, mixing, and removal of gaseous and particulate pollutants in ambient air,
- Model the kinetics of chemical reactions of atmospheric pollutants,
- Understand by laboratory and field research the incorporation of sulfur and nitrogen oxides into cloud water with the consequent formation of acid rain,
- Understand through observation and theory, the radiative transfer and fluxes in the atmosphere,
- Analyze data and develop parameters relevant to global climate change,
- Analyze the Texas 2000 Air Pollution Study and the Vertical Transport and Mixing Experiment.

The DOE-OBER also supports research to understand and identify the sources, destinations, and impacts of carbon dioxide in our global environment. The BNL's Terrestrial Carbon Cycle program investigates the natural carbon cycle, including quantifying the role of the terrestrial biosphere as a sink or source of carbon dioxide. In the Duke Forest in North Carolina, BNL established and operates the Forest Atmosphere-Carbon Transfer and Storage Experiment (FACTS-1), to study processes regulating forest carbon balance. A specific objective is to quantify the physiological processes controlling CO_2 fluxes in a pine forest under ambient and elevated atmospheric CO_2. BNL also supports the development of Free-Air CO_2 Enrichment (FACE) facilities, and coordinates work across FACE sites by maintaining collaborations, managing data, visualization, integrative modeling, and by coordinating data submissions to the Carbon Dioxide Information Analysis Center (CDIAC). To improve predictions of future atmospheric CO_2, the coupling between photosynthetic organisms and the atmosphere must be understood. New tools in molecular biology are being applied to determine how carbon uptake by plants adjusts to increases in atmospheric CO_2. A novel system to measure non-destructively soil carbon using inelastic neutron scattering is being developed for field use.

The objective of the DOE-OBER's Natural and Accelerated Bioremediation Research Program (NABIR) is to gain a fundamental understanding of complex phenomena to reduce or prevent pollution to protect human health and the environment. This research provides the basic scientific knowledge needed to make bioremediation a viable option for dealing with DOE's most challenging clean-up problems. The goals of the Molecular Genetic Analysis program include sequencing the ends of *Clostrida* genomic fragments, analyzing the nucleotide sequences in detail to identify regulatory elements, and complete the sequencing of regions of high biological relevance. A related program is exploring the transformations of heavy metal ions in anaerobic systems undergoing bacterial sulfate reduction to understand the fundamental processes for reducing and precipitating heavy metals as sulfides in subsurface environments. Researchers also are exploring the fundamental mechanisms by which natural microbial communities stabilize soluble organic and inorganic plutonium complexes. Results from this research will lead to (1) a better understanding of environmental conditions likely to retard plutonium mobility and transport, and (2) strategies for engineering the long-term immobilization of plutonium in soils and sediments.

The DOE's Office of Basic Energy Sciences also funds basic research in the nucleation dynamics of microparticles, and chemical characterization of ultra-fine particles to provide analytical tools to study the physical and chemical characteristics of microparticles that are common atmospheric aerosols. The DOE-BES Geoscience program funds research in microtomography to determine the microgeometry and microcomposition of different types of geological materials. Research includes measuring at a spatial resolution of 0.0002 mm, core samples from the Ocean Drilling Program, from sea floor black smoker chimneys, sandstone, and carbonates. In another program, researchers study the chemistry of polysulfides in rich marine sediments, the incorporation of sulfur into organic matter, and their effects in preserving sedimentary organic matter. These programs may aid the search for new petroleum deposits and offer a clearer view of the sulfur compounds found in petroleum.

Near-term Program: In the Atmospheric Sciences program, researchers will continue field studies of the chemical and physical properties and fate of energy-related pollutants. Field studies from the Phoenix, Philadelphia, and Houston areas will be completed, and work will be underway to study the transport of pollutants and their precursors from the industrialized mid-west to the east. New and improved instruments for field studies will be used, depending on the needs of future field programs; this includes new instrumentation for rapid *in situ* measurements taken from aircraft of the size distribution of ambient aerosols and the chemical composition of individual particles. Specifically, we will construct a second-generation single particle mass spectrometer that can be used aboard research aircraft. Laboratory work will continue on defining the mechanistic role of multiphase chemical processes in producing photooxidants and aerosols in the troposphere, including the development of analytical methods to characterize aerosol organic constituents, to measure the gas phase concentration of nitrous acid, and to improve capabilities to gain size-related composition for organic and inorganic components in aerosols. A laboratory based second-generation single particle levitation instrument will be constructed.

Researchers will develop methods to use the BNL aerosol model to designate the boundary and initial conditions for higher resolution models to accurately represent the impact of exogenous aerosols to areas of interest. The BNL sulfate model will be converted into an operational one. Meteorological data from the U.S. National Centers for Environmental Prediction will be acquired automatically and reduced to provide necessary input for the BNL aerosol model. Researchers will continue to develop models and parameters for short-wave radiative forcing by aerosols, using ARM data to gauge their accuracy and uncertainty, and to develop and code a model to evaluate aerosol short-wave forcing from vertical profiles and a model for down-welling radiation. The cloud microphysics of liquid water clouds in general circulation models needs improving and we are concentrating on understanding the relationship between the concentrations of cloud condensation nuclei, cloud turbulence, and cloud microphysics. Our approach is to develop and test parameterizations of cloud microphysics using measurements from the ARM cloud and radiation test bed. Work will continue on understanding solutions under extreme conditions, particularly the dynamics of nucleation, and researchers will develop new systems to investigate nanoparticles and initiate work on ice nucleation under upper tropospheric conditions.

Researchers in the Terrestrial Carbon Cycle Program will continue to operate the FACTS-1 facility at the Duke Forest. Measurements of canopy photosynthesis, conductance, and leaf area index will continue. Laboratory and field investigations will continue to improve, refine, elucidate, and validate mechanisms that control how plants adjust their uptake of carbon and nitrogen to increases in carbon dioxide. Understanding the relationship between carbon and nitrogen metabolism is essential in predicting the response of terrestrial ecosystems to global change. Emphasis is on the long-term effects of global change, and our focus is to be able to scale our findings to the ecosystem level by improving our mechanistic understanding of biological processes.

We will plan and build the software tools necessary to produce a computer-modeling platform suitable for the FACE and AmeriFLux communities. The FACE engineering group will improve the design and control systems to improve the efficiency of carbon dioxide use and control of its concentrations. They will participate in, and supply instrumentation to determine the spatial and temporal footprint of AmeriFlux measurements of net ecosystem exchange of carbon dioxide. Separately, we will develop practical field instruments to measure carbon in soil using inelastic neutron scattering.

We will continue work for the OBER NABIR and explore the interactions between humates and uranium-organic complexes at the NABIR Field Research Site. BNL's accelerator physicists and environmental scientists are evaluating synchrotron-based molecular research in environmental sciences conducted during the past few years at the DOE light sources to identify work that would benefit the DOE's environmental clean-up efforts and the basic research underpinning these efforts.

For the Office of Basic Energy Science, BNL expects to develop a general picture of the nucleation process far from equilibrium, and to establish a new system to extend the study of phase transformations to nanoparticles. In the geoscience program, BNL will expand and refine computed microtomography and will improve measurement and visualization technologies. Investigations of the properties of geological material, including microstructure, fractures, and fluid flow at the micrometer scale will be done using computer microtomography at the NSLS. Research also will continue on the transformation of organic matter during the progression from early to late diagenesis; studies on marine sediments will be expanded to determine the nitrogen speciation in macromolecular organic matter using x-ray absorption near edge spectroscopy (XANES).

Future Program: BNL plans to grow and extend the environmental science program in four areas. The NSLS accelerator physicists and environmental scientists are developing new synchrotron applications useful to molecular environmental science, environmental cleanup, and geosciences communities. Additional staff will implement these applications at the NSLS and offer scientific and technical support to new users. Scientists skilled in modeling and visualization will complement the already strong experimental programs in Atmospheric Science and Terrestrial Carbon Cycle research. BNL's perfluorocarbon tracer technology is used in the DOE's Terrestrial Carbon Cycle and Atmospheric Science programs and several DOE Environmental Management (EM) science and technology efforts. The tracer group will continue advancing tracer technology by making available more types of tracers and by expanding their analytical capabilities. In addition, BNL will connect the basic research conducted in the Biology Department with the more applied research in the Environmental Sciences Department.

5.2.6 Life Sciences: Medical and Imaging Sciences (KP)

Medical imaging and addiction studies remain the cornerstone of OBER research at BNL. This research mission creates great opportunities for collaborations and jointly funded initiatives with other agencies, principally the National Institutes of Health (NIH). BNL has a unique combination of facilities and expertise for performing world-class research in the medical and imaging sciences. Researchers use nuclear technology, radiopharmaceuticals, and synchrotrons to develop new treatments, new diagnostic tools, and to study human physiology and the mechanisms of disease in oncology and neuroscience. The programs uses BNL's unique facilities including the Brookhaven Linac Isotope Producer (BLIP), the Booster Application Facility (BAF), the Alternating Gradient Synchrotron (AGS), and the National Synchrotron Light Source (NSLS). The overall research is funded not only by the DOE, but also by the NIH and NASA.

5.2.6.1 Imaging Research

The medical imaging program, a joint effort of the Chemistry and Medical Departments, has the following program goals:

- Conduct basic research in radioisotope and radiotracer chemistry.
- Develop and apply new aspects of magnetic resonance imaging.
- Develop new imaging modalities.
- Carry out basic and clinical studies in the neurosciences.

Present Program: The cornerstone of the Positron Emission Tomography (PET) Program is the production of cyclotron-based positron emitting isotopes and rapid synthesis of radiotracers for imaging specific molecular targets, and for studying drug distribution and kinetics. Researchers conduct basic and clinical neuroscience research using PET to investigate neurotransmitters and their interactions, to characterize the molecular changes occurring in addiction, and to use new knowledge to develop treatments for addiction. BNL also has a long-standing commitment to investigate the molecular changes underlying normal aging and their relationship to neurodegenerative disease and its treatment. A second objective is to investigate the actions of therapeutic drugs in the human body to optimize their beneficial effects, minimize toxicity, and expedite their introduction into the practice of health care. We are developing tracers to characterize the molecular properties of tumors and to use imaging to investigate different facets of radiation therapy. Among the facilities available for this work are two cyclotrons (41" and 60"), one radio frequency quadrupole (RFQ) accelerator, two large PET scanners, one micro-PET camera for rodents, one Single Photon Emission Computed Tomography (SPECT) scanner, and an animal PET (MicroPET).

The Magnetic Resonance Imaging (MRI) facility is equipped with a 4 Tesla instrument for studying humans and animals. The major research goal at the High-Field MRI Laboratory is to develop and refine innovative Nuclear Magnetic Resonance (NMR) techniques to image and measure the physiology, function, and chemistry of tissues *in vivo*. The upgrade of the MRI scanner in FY 01 allows us to perform these measurements using ultrafast MRI scans. The techniques developed at the High-Field MRI Laboratory are continuously transferred to the human arena to improve our understanding of brain function and chemistry in healthy subjects and patients with disorders, such as drug abuse, HIV infection, Alzheimer's, and other neuropsychiatric diseases.

Furthermore, integrating the PET and MRI imaging modalities within a single center at BNL offers a unique opportunity for basic research in developing, validating, and applying novel imaging methods, and for investigating the synergistic uses of multiple imaging modalities to probe the molecular mechanisms involved in normal brain function and disease. The MRI program was expanded with the recent hiring of three new scientists. The next generation scanner, a 7 Tesla MRI instrument, is anticipated very soon.

Future Program: Next year we will further integrate the Micro-PET with our radiotracer R&D efforts. The DOE-OBER funded a new negative ion cyclotron dedicated to isotope production for the PET program. It is expected to be operational early in FY 03 and will replace the 41" cyclotron that has become increasingly unreliable and difficult to repair. This new machine will be more reliable, simpler to operate, and be able to irradiate two targets simultaneously, alleviating some of the time constraints experienced with the present cyclotrons and the need to supply isotopes for three scanners.

In conjunction with the University of Stony Brook, we purchased a new high field magnetic resonance imaging instrument for functional and spectroscopic studies in animals. This scanner will be operational early in FY 03 and will expand our capabilities for imaging rodents and other small animals.

Other planned research in the Imaging Program includes continuing the initiative in biomedical engineering, expanding our capabilities in computing software for routine fusion of PET and MRI data sets, and continuing to develop *in vivo* approaches to assess gene expression and gene delivery.

5.2.6.2 Isotope Research and Production Program

Present Program: The goals of the Isotope Research and Production Program are to develop, produce, evaluate, and distribute new radionuclides (or those not in production elsewhere) and radiopharmaceuticals that would lead to the following:

- improved diagnostic and therapeutic procedures in nuclear medicine, particularly for oncology, cardiac disease, and neurosciences, and
- a better understanding of physiological processes in health and disease.

Many unique Laboratory facilities (BLIP, cyclotrons, high-level radiation processing facilities, radiochemical laboratories) as well as protocols for animal testing and clinical studies, are part of this program. The BLIP is a unique national resource producing many isotopes crucial to nuclear medicine for both research and routine clinical use in patients, and that generally are unavailable elsewhere. The BLIP facility supported new radiopharmaceutical developments at BNL and the distribution of many difficult-to-produce isotopes to industry and to research investigators.

We continue to investigate the use of radioisotopes, such as Sn-117m, for cancer therapy and for treating painful bone metastases that are frequent in patients with advanced breast, prostate, and lung cancer. We use isotopes produced at the BLIP for labeling monoclonal antibodies that are directed against antigens expressed in breast, colon and other cancers. We continue to refine the immunoconjugates labeled with certain positron emitters developed in FY 01 that may be useful in the early detection of breast and colon cancer. Molecular engineering could enhance the cytotoxic potential of radiolabeled antibodies, and we are working on fusing viral proteins to antibodies to increase the uptake of the labeled conjugate into tumor cells. These antibodies could be used to image or destroy the tumor.

Future Program: In the future, we will continue to focus on the following key research areas:

- Develop new isotopes (e.g., no-carrier-added Tin-117m, Scandium-47 and Mercury-195m), and associated radiolabeling methodology.
- Construct radiolabeled, bioengineered molecular antibodies from single chain antibodies and viral vectors, for imaging gene expression and gene/radioisotopic therapy of cancer.
- Conduct clinical studies of Tin-117m chelates for palliating metastatic bone pain and for treating primary/metastatic bone cancer and rheumatoid arthritis.
- Develop targeted tumor therapy by using radiolabeled anti-angiogenic peptides, matrix metalloproteinase (MMP) inhibitors, and STTR-binding peptides.

A major Laboratory initiative is a new 70 MeV Cyclotron Isotope Research Center described in Section 4.6.

5.2.6.3 Cancer Research

Present Program: Our goals in cancer research are to develop new forms of radiation based treatments for cancer, including Microbeam Radiation Treatment (MRT) using the National Synchrotron Light Source.

Conventional radiation therapy (XRT) can be ineffective. Its failure appears to be primarily related to constraints on delivering the radiation dose due to the critical morbidity of normal tissues. Radiation is thought to damage the normal Central Nervous System (CNS), in part by injuring endothelial cells in the microvasculature. Microbeam Radiation Therapy (MRT), an innovative method of irradiation initially developed at the NSLS, appears to overcome this limitation of conventional therapy. MRT uses synchrotron-generated beams segmented into parallel, microscopically thin (<100 μm) planar slices of radiation (called microplanar beams, or microbeams). Our preliminary studies show that unidirectional, single-fraction MRT preferentially kills intracranial gliomas in rats at doses that are tolerated by the normal brain tissue, while normal-tissue studies at the NSLS and recently at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France, show that normal tissues tolerate single exposures to microbeam irradiation at in-beam doses 10- to 20-times higher than single-fraction conventional broad beams. This tissue-sparing effect of MRT may be due, in part, to differences between the microvasculature of the normal tissue vs. tumor tissue. One possible mechanism of this sparing may be that endothelial cells lying between the microbeams survive, and later replace their lethally injured neighbors.

In parallel, we are developing radiotracers for PET imaging that may be useful for the early detection of cancer. These include [^{11}C]boro-phenylalanine, an amino acid analog formerly used with Boron Neutron Capture Treatment (BNCT). This ligand can be used to provide information on the delivery of *p*-boronophenylalanine or BPA into the tumor, which is important for planning appropriate treatment.

Future Program: We propose to extend the microbeam research to include the following:

- Investigate the radiobiological mechanisms underlying MRT's ability to spare normal tissues and preferentially kill tumors.
- Optimize the MRT dose by finding the best beam width and spacing in the array for each subject, optimize the administration geometry (i.e., unidirectional versus different cross-fired configurations), examine the potential of dose-fractionated MRT, and evaluate possible synergy between MRT and administration of a gadolinium-based contrast agent (Gadovist) as a sensitizer, to determine the best therapeutic index in a variety of tumor models.
- Irradiate animals inside a plastic head phantom to simulate the effects of tissue depth in clinical MRT.
- Study the potential of microbeams for re-treating tumors.

Our long-term goal is to extend these studies to large animals to examine various effects, such as damage to the proximal normal tissue in irradiating deeply seated tumors, cardiosynchronous tissue pulsation, and long-term central nervous system effects so we can evaluate the potential of MRT in clinical radiation therapy. If these studies and others indicate a clear clinical application, limited Phase I human studies could be conducted at the NSLS X17 beamline. Recent advancements in the design and fabrication of small, dedicated synchrotron storage rings of high beam energy and intensity indicate that such a facility could be developed for MRT in a clinical setting.

5.2.6.4 Medical and Imaging Science Program Initiatives

For the long-term program, BNL is proposing several program initiatives in medical and imaging sciences; the Laboratory for Cell Biology, Behavior and Functional Genomics, new directions in our cancer and radiobiology research programs, Imaging Instrumentation Development, and Radiotracer Applications to Environmental Studies.

Laboratory for Cell Biology, Behavior, and Functional Genomics: A new initiative, Imaging Gene Expression, received support from DOE in FY 2002. Our goal is to measure the *in vivo* binding of labeled oglionucleotides to mRNA that will allow imaging of gene expression using PET. If successful, this work will be highly complementary to, and supportive of, the major DOE initiative of bringing the "Genomes to Life." We plan to develop a laboratory that will provide a mechanistic and functional framework for both human and animal PET- and MRI-imaging studies on addiction, aging, drug development, and cancer. This will enhance our on-going research to develop and validate new methods for assessing gene delivery, and the functional activity of specific gene products (receptors, enzymes, transporters) in normal and genetically altered animals. We will add a particularly important aspect, a strong animal behavior component, to complement and enhance our current capabilities (microdialysis, electrophysiology, and *in vitro* binding) for understanding and treating addiction. This laboratory will facilitate the integration of the imaging and NASA Space Medicine projects to investigate the behavioral, cognitive, and motor consequences of increased radiation burdens in space.

Cancer Research Initiative: We will build on our current strengths in radiotracer development and nuclear imaging, radiation therapy, and the applications of the NSLS in diagnosis and treatment to consolidate and expand BNL's efforts in cancer research. PET imaging will be developed further to characterize the molecular properties of human tumors and to map drug distribution and kinetics to understand the therapeutic and side-effects of anticancer drugs, different types of radiation therapy in normal tissues as well as the mechanisms accounting for its toxicity in malignant tissue, and the potential clinical applications to malignant brain tumors. Progress in the last year included obtaining an investigational new drug application (IND) from the FDA to use a new F-18 labeled radiotracer for the enzyme catechol-O-methyltransferase (COMT) to image estrogen metabolism in breast tumors to enhance our understanding of them and their early detection. We formed a collaboration with the Department of Surgery at Stony Brook University to investigate the use of radioisotopes, such as (Sn-117 nDTPA), for the palliation and treatment of bone metastases that are frequent in patients with advanced breast cancer. Our new efforts will include exploring new BLIP-produced radioisotopes coupled to monoclonal antibodies that are directed against antigens expressed in breast cancer cells. In addition, BNL recently developed immunoconjugates labeled with certain positron emitters that may be useful in the early detection of breast cancer using high resolution PET imaging; molecular engineering could enhance their cytotoxic potential. We are fusing viral proteins to antibodies to increase the uptake of the labeled conjugate into tumor cells; these antibodies could be used to image or destroy the tumor. An important component of the Cancer Initiative is our strong tie with Stony Brook scientists and the new Stony Brook Cancer Center.

Neuroscience Initiative: We plan to expand the neuroscience program to investigate the role of genes in normal brain function and in neuropsychiatric diseases. We will recruit a leader in the field of genetic-neuroscience who will develop methodologies that use imaging tools to measure gene expression *in vivo* in the brain. This initiative also involves expanding the collaborations between the Imaging Group (Chemistry and Medical Departments), the Biology Department, and the Center for Data Intensive Computing. In parallel, we expect this approach to facilitate the DOE's Biomedical Engineering Initiative since it will promote discovery of novel imaging methodologies, instrumentation, and radiotracers. It also will further the Neuro-Informatic Initiative at NIH since it will require developing new analytical tools for data analyses.

Biomedical Engineering Initiative: In a related effort, we launched a major initiative in biomedical engineering, Imaging the Awake Animal Brain. This topic is very important because now imaging can be performed only during anesthesia to minimize motion artifacts. However, it is extremely difficult to assess brain function, chemistry, and physiology in animals that are in an artificial coma. The main goal of this initiative is to develop novel technologies, particularly for PET and MRI, that can image the brain of the awake animal (rat or mouse) in real-time and under natural physiological conditions. This work includes developing motion tracking and restraint devices, as well as reducing acoustic noise in MRI. Most techniques will have applications beyond animal imaging, such as compensation for motion and correction in human PET and MRI studies. We compiled a strong multidisciplinary research team involving investigators from five BNL department/divisions, from Lawrence Berkeley National Laboratory, and from the Stony Brook University Medical Center.

Imaging Instrumentation Development for PET: We started a program to develop new specialized PET imaging instruments, based on innovative designs and special applications (e.g., positron-detector probes for freely moving animals, arterial blood detectors, and a rectilinear scanner for rapid kinetics in small animals). We are evaluating prototypes for these devices, and the results are very encouraging. We obtained DOE bioengineering funds and entered into a Cooperative Research and Development Agreement (CRADA) to partially fund this initiative. However, a major cost and limiting factor will be funds for scintillation crystal detector modules and the associated electronics needed to scale-up the prototype devices.

Imaging Instrumentation Development in MRI: With scientists from BNL's Magnet Division, we are evaluating the possibility of designing an MRI that will allow motion during scanning. This would be particularly desirable for MRI studies in animals where the use of anesthesia directly affects the processes under investigation.

Space Biomedical Engineering Initiative: The recent characterization of neural stem cells has stimulated considerable hope that these cells might be potentially useful for repairing the human central nervous system in degenerative neurological diseases, recovery after trauma, and as delivery vehicles for gene therapy. The goal of this initiative is to investigate the possible value of microgravity conditions for the proliferation and expansion of such cells by analyzing their multi-potentiality, differentiation capacity, and functional activity *in vitro* and *in vivo*. In collaboration with the NASA Johnson Space Center and the Biotechnology Center at Stony Brook University, we will establish a laboratory to develop *in vitro* systems using bioreactors and animal models to study the biology of neural stem cells and neurons.

Diffraction Enhanced Imaging Initiative: Despite recent advancements in mammography, MRI, and Computed Tomography (CT), challenges remain. The rate of false negatives in mammography is about 10%; cartilage is difficult to visualize by radiological means, and the contrast of a chest is too low to detect early stages of emphysema and edema. Diffraction Enhanced Imaging (DEI) is a new radiography method that extracts phase-contrast information, in addition to traditional absorption contrast. Chapman, Thomlinson, Zhong, et al. developed the method in the mid 1990s at the NSLS in a collaboration that included scientists from the University of North Carolina, and applied it mainly to mammography studies. Such studies are ongoing at the NSLS X15A beamline. A new high-resolution CCD detector (50 μm pixel size) funded recently by the NSLS will be available for this program. A proposal will be submitted to the National Institute of Bioimaging and Biomedical Engineering in November 2002. NIH's Bioengineering Research Partnership recently funded a similar one. The proposed program will include pre-clinical imaging studies in breast and lung using a wide range of beam energies, 18-60 keV, from both the X15A bending magnet beamline and the X17B1 superconducting wiggler beamline. The higher beam energy improves transmission through large body sections and reduces the subject's absorbed radiation dose. The proposed research also will include finer angular acceptances compared to those used in current studies to enhance the sensitivity of DEI, and finer spatial resolution to improve the image quality. The studies will be carried out in both the planar radiography and the CT mode.

Low Dose Radiobiology Initiative: Mammalian cells exposed to very low doses of low Linear Energy Transfer (LET) radiation not only suffer damage, mainly to their DNA, but also exhibit altered signals over prolonged periods. Although altered signaling is related to adaptive responses, including conventional protection against endogenous DNA damage, and disappears with increasing dose, its mechanisms are not well understood. These phenomena are at the center of interest today and are the underlying effects that determine the risk from environmental and occupational radiation. By studying them, we can re-examine the scientific validity of the linear-no-threshold hypothesis.

We plan to study the low-dose effects using a special monochromatic microbeam from the NSLS's X15A beamline to target individual cells *in vitro* with 8-keV monochromatic beams that mimic the effects of the environmental, occupational, and medical exposures. A proposal was submitted to the DOE OBER. The dose range proposed, 0.5 to 100 cGy, will allow detailed mapping of the interplay between the effects of radiation damage and the protection induced by the altered cell signaling effects. The proposal includes using a dedicated beamline at the NSLS to establish a National Microbeam Facility for Low-Dose Radiobiology. The work is a collaboration among BNL, Columbia University, and New Jersey Medical School.

Radiotracer Applications to Environmental Studies: BNL and Stony Brook University, Department of Ecology and Evolution, are collaborating in a research initiative to use short-lived radiotracers to probe the mechanisms of biosphere/atmosphere exchange emphasizing pollutant exchange between plants and the atmosphere, including nitrogen dioxide, carbon monoxide and hydrocarbons. The project is in its early stages, and if funded, we intend to actively pursue it using BNL's Cyclotrons, Radiotracer Laboratory, and core scientific expertise.

5.2.7 Biological Science - Molecular and Structural Biology (KP)

The new DOE initiative, Genomes To Life (GTL), provides an exciting focus for the expertise developed over many years in the Biology Department to understand the basic principles of biological interactions both at the molecular level and within ecosystems comprised of microbes and higher forms of life. In response to the initial call for GTL proposals, a group of scientists from BNL, other National Laboratories, and academic institutions submitted a joint proposal to develop cutting-edge, high throughput DNA sequencing methods to identify and quantify microbes in the environment, analyze gene expression profiles in microbes and plant roots within soil communities, and track changes in gene expression in response to environmental stimuli and following contamination of soils with radionuclides or heavy metals. The development of these ultra sensitive sequencing methods will allow scientists to monitor microbial species that cannot be propagated as pure cultures in the laboratory, and identify coordinately regulated genes that may define novel metabolic pathways responsive to environmental stress. The work is relevant to the DOE's efforts to develop renewal resources for carbon management.

Subsequent calls for GTL proposals will focus on the major goal of characterizing interactions that enable proteins to function together as cooperative "molecular machines". This goal is strongly supported by strengths in structural biology and protein expression, and long experience with characterizing the biochemistry of protein complexes derived from bacterial, plant, and mammalian cells. The STEM and new CryoEM microscopy facilities are well matched to the GTL's objective of developing methods for imaging protein complexes in living cells or in fixed sectioned cells. Therefore, the prospects are promising for the Biology Department's expertise in several areas to flourish under the GTL program.

In FY01, BNL's Biology Department formed the Center for Complex and Membrane Protein Structures. Membrane proteins are critical elements of biological processes and are directly related to understanding the consequences of energy generation and its use and the impacts on human health and the environment. Membrane proteins and protein complexes are important targets in cell signaling, human function, and bioremediation. They function in the brain as receptors for neurotransmitters and in microbes as transporters, yet they account for less than 1% of known protein structures. To attack this difficult problem, strengths in molecular biology and biochemistry need to be brought together with the appropriate analytical tools. The staff was enhanced by recruiting a Membrane Protein Crystallographer, a critical skill for this center. Two molecular microbiologists, experts in membrane protein systems relevant to bioremediating soils, joined the staff to focus on the DOE's Genomes to Life Initiative.

Other research programs also require state-of-the-art analytical tools. A key component supporting the Genomes to Life Initiative is the new Cryogenic Electron Microscope (CryoEM) facility. There researchers analyze two-dimensional arrays of membrane proteins, isolated complex particles, and frozen tissue sections. The DOE provided funds to purchase a CryoEM, and BNL is establishing the infrastructure to install and operate it in an integrated manner with the STEM facility.

The Department also operates a Macromolecular Crystallography Facility that includes five beamlines at the NSLS. The beamlines continue to be oversubscribed and fully utilized, and "FedEx" operations have been expanded. This is the process wherein outside users mail specimens to BNL for our staff to collect data. Beamline X26C now is equipped with a triple beam diffractometer. Recently, visiting scientists used it to investigate the protein-solvent interface on insulin. This Facility's operation is described in more detail in section 6.1, Work for Others.

User facilities also are available for radiation biology research, including cell culture and small animal facilities that are primarily used to support NASA funded activities; they include the shielding cave at AGS containing the beam and the biological experimental station and laboratory facilities. A 10ft. long optical bench for exposing samples is available in the cave, as well as the beam handling, sample changing, and dosimetry instrumentation. The biological experimental station contains one area for cell culturing equipped with a laminar flow hood and incubator, a short-term animal holding facility, and an area for physics/run-control. Laboratory space and animal facilities accredited by the AAALAC are available in the Medical Research Center.

Present Program: The DOE's Office of Biological and Environmental Research (OBER) sponsors research in molecular, cellular and structural biology in conjunction with other offices in DOE (BES, NN, and EM), other federal entities (particularly the NIH), private foundations, and collaborating industries. These programs extend from the molecular level to that of the whole organism and address basic questions in molecular genetics, cell biology, and structural biology that support the DOE's objectives and provide insights and tools relevant to areas of the DOE's interest. They include the following projects:

- Identify and characterize cellular mechanisms that detect DNA damage, repair it, and prevent oncogenesis.
- Analyze genomes, gene expression, and proteomes of model organisms.
- Understand enzymes and enzyme systems that carry out fundamental processes of life.
- Use biology for humankind, including engineering systems for improved bioremediation.
- Develop and validate complex tools for determining protein structures for use in research worldwide.

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BNL researchers have a long and distinguished history of research on DNA damage and repair, both defining the basic biochemistry and genetics and developing tools for accurate and sensitive measurements. Using recently devised methods for measuring clustered DNA damage – two or more closely spaced strand breaks, abasic sites, or oxidized bases on opposing strands – researchers demonstrated that the frequency of cluster damage induced by ionizing radiation is comparable to that of frank double-strand breaks. They also developed an improved method to acquire sequence data from regions of DNA that are refractory to analysis by standard methods. The new method uses transposon insertion to introduce regulatory elements into cosmid or bacterial artifical chromosome (BAC) clones, enabling the clones to replicate to high copy number within bacterial host cells.

Double-strand breaks and clustered damage are repaired in mammalian cells primarily by two mechanisms. One involves DNA end joining by components regulated by the DNA-dependent protein kinase. Recent studies show that the large catalytic subunit of this kinase consists of domains that are stable to proteinase digestion. At least some of these domains can be expressed as recombinant proteins in eukaryotic systems, potentially paving the way for a detailed structural analysis. BNL scientists also developed methods to detect specific phosphorylation events in proteins that occur in response to ionizing radiation and other forms of DNA damage. Such reagents can trace the pathways of response to DNA damage and those that regulate cell cycle progression, apoptosis, and DNA repair.

A method was developed to identify and qualitatively analyze genomic DNAs (called Genomic Signature Tags) that provides limited representation of all the DNA molecules in a given population without the need for any prior knowledge of the DNA sequence. This method potentially could be used to detect the presence of biological warfare agents in crude environmental samples. It also will be used in the GTL project to characterize the composition and dynamics of natural populations of microbes in normal and contaminated soil samples.

A pilot project in functional genomics began in FY 1998 to test the potential of high-throughput protein crystallography for obtaining structures for representatives of protein families for which such information is lacking. Genome and cDNA sequencing projects provide a rich source of data for identifying protein families and obtaining coding sequences for selected proteins. Efficient methods based on 96-well format techniques for efficient genome sequencing are being adopted to identify and express selected protein domains. Recent studies of 95 yeast proteins indicate that at least half are likely to produce soluble proteins suitable for crystallographic studies. However, several issues that must be resolved were identified; they include insolubility resulting from peptide tags and errors introduced during polymerase chain reaction (PCR) amplification and cloning. The NSLS is ideal for obtaining diffraction data rapidly and efficiently; therefore, we believe we can make an important contribution by developing methods for understanding protein structures. Accordinly, we have partnered with our neighboring institutions, The Rockefeller University and the Albert Einstein College of Medicine, to form a Structural Genomics Research Consortium. We anticipate that this consortium will be funded primarily by sources other than the DOE; nevertheless, the expected results will directly support the DOE's missions in human health, bioremediation, and carbon management.

Many of our research programs use our facilities for Structural Biology to analyze structures and interactions of biologically important proteins and their complexes, including the following:

- structures of viruses, chromatin, and ribosomes,
- interaction of a viral attachment protein and the receptor on the host cell,
- the outer surface proteins of pathogens (including the antigen used in the vaccine for Lyme disease),
- toxin structures, protein chaperons, DNA repair complexes, and DNA modifying enzymes.

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BNL has an extraordinary combination of strengths in molecular genetics, structural biology, genomics, and biotechnology. The Laboratory's highly interactive research environment is the ideal incubator from which complex user facilities for structural biology can be developed and optimized for the wider research community. There is a growing demand for these facilities. We continue to partner with outside groups who invest in upgrades or construction of new protein crystallography facilities at the NSLS, thereby increasing overall access for our users.

The Laboratory's Scanning Transmission Electron Microscopes (STEM I and III) are available for high-resolution measurement of shapes and masses of biological molecules and their complexes. The types of information that can be obtained include three-dimensional location of atoms in individual molecules or complexes, the arrangement of molecules in higher order structures, and the overall shapes and interactions of complexes of molecules. Such information is essential for understanding how biological molecules and structures function. Recent successes include the development of new gold-labeled tags for identifying important functional sites in proteins, such as ATP binding pockets. Anticipated improvements in the detector technology of STEM III should permit locating specific atoms, including phosphorous and boron.

Future Program: The Laboratory aligns its research programs to the interests of the OBER, with particular emphasis on the Genomes to Life Initiative. Near-term objectives include the following:

- Institute programs to characterize and measure the effects of low dose and low-dose rate ionizing radiation on human cells and human health, and to characterize the effects of genetic diversity on the responses to DNA damage.
- Sequence difficult regions of human DNA, and develop and validate vectors to improve genome sequencing.
- Develop capabilities for characterizing gene expression at the mRNA level from organisms that are important for bioremediation and carbon management, as well as from a specific region of the human brain; produce cDNA libraries enriched for full-length cDNAs and assist in their analysis.
- Characterize complexes involved in signaling the presence of, and repair of, DNA strand breaks and complex damage in human cells, and initiate studies to determine the structures of the proteins involved.
- Continue to develop technology for efficient, high-throughput protein crystallography to demonstrate the feasibility of a structural genomics component of a Human Proteome Project in partnership with universities and in coordination with other national laboratory centers.
- Continue to determine the structures and interactions of biological complexes, improve the methodology, and engineer proteins.
- Continue to improve our user facilities for structural biology, focusing on improving the efficiency of protein crystallography at the NSLS and the user's ease of access.
- Strengthen and extend radiobiology research to investigate the cellular mechanisms involved in radiation induced cell damage; investigate the effects of heavy particle radiation that mimics radiation effects in space on cells and whole organisms; and, develop an *in vitro* radiobiology facility at the NSLS X15A beamline that uses precisely collimated beams to target separately the cell nucleus and the cytoplasm in tissue cultured cells.

We propose to establish a group to completely re-engineer software for phasing, model building, and structure refinement for protein crystallography, greatly reducing the need for human intervention. Without substantial automation, the process of converting synchrotron data to fully refined structures will become a serious bottleneck in high-throughput protein crystallography. Additional scientific staff and expanded collaborations with the State University of New York at Stony (SUSB) for research and training in bioinformatics and computational biology are planned as part of the Center for Data Intensive Computing. In this partnership with the SUSB and others, BNL will increase its capabilities for determining structures of membrane and complex proteins to support the DOE's initiatives in carbon management, bioremediation, and the Microbial Cell, as well as strengthen a partnership within BNL in DNA damage signaling and brain function.

5.2.8 Educational Programs (KX)

Present Program: The DOE's Office of Science, in conjunction with other agencies, supports an educational mission at the Laboratory. The goals of BNL's Educational Programs include the following:

- To enrich the training of future scientists and engineers by
    - developing excellent educational programs, resources, and activities that take advantage of BNL's world-class, cutting edge and unique scientific research.
    - providing research internship programs for undergraduates to support the Department of Energy's scientific mission,
    - providing enriching educational experiences and career pathways in mathematics, science, engineering, and technology for a diverse group of pre-college and undergraduate students,
- To increase science literacy in schools by
    - enhancing the preparation of pre-service math, science and technology teachers
    - providing professional development opportunities for in-service math, science, and technology teachers,
- To form a community of students, teachers, scientists, engineers, and others who share a passion for science and science education by providing resources and activities that support the Laboratory's efforts in Community Involvement and Public Outreach, and contribute to its role as an educational resource and valuable asset for the local and national community.

Undergraduate Internship Programs: In these programs, students work with a mentor on an authentic research project so that they become a part of the scientific community and gain valuable research skills. For example, many students in the Energy Research Undergraduate Laboratory Fellowship (ERULF) Program co-author scientific papers that are published in refereed journals. The Community College Institute (CCI) helps to increase the diversity of the student population at the Laboratory and contributes to building the technical workforce of the future. The Pre-Service Teacher Program (PST) provides research experiences to undergraduates who are committed to careers in teaching math, science, or technology. They also work with Master Science teachers who help them apply what they learned at the Laboratory to the classroom. A new program beginning in 2002, supported by the U.S. Support Group ISPO, provides undergraduates with research internships with mentors from the International Atomic Energy Agency. Over 100 undergraduates participate in internships each summer at the Laboratory.

Conferences, Workshops, or Summer School: These gatherings offer educational enrichment in areas where the Laboratory has unique capabilities. They include a Nuclear Chemistry Summer School, Undergraduate Mini-semesters, and two summer programs for high school students, (the Minority High School Apprenticeship Program for 9th and 10th grade students and the Community Summer Science Program for high school juniors and seniors). All are linked to the research programs at the Laboratory.

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Informal Education Programs: The BNL Science museum offers elementary and middle school students a variety of hands-on, minds-on, inquiry science experiences related to research at the Laboratory. The museum's staff conducts outreach programs for elementary schools, such as "Magnets to Go." Professional development workshops for elementary school and middle school teachers also are held at the museum. This year, undergraduate students in the PST program are working with the science museum staff to evaluate these educational programs. A summer camp is being offered for the first time that will concentrate on topics related to "Energy and the Environment."

Teacher Enhancement Programs: A variety of programs and resources exist at the Laboratory for math, science, and technology teachers. Local physics teachers participate in Quarknet, and a Cosmic Ray Project. Two different Math and Science Partnership grant proposals were submitted to the National Science Foundation; one is a partnership with SUNY Stony Brook and Hofstra University and will involve working with grades 5-8 math and science teachers from ten regions of New York State. The other partnership is with Southampton College and a consortium of other institutions that also will involve professional development for grades 5-8 math and science teachers from three local school districts. Courses, including distance education, are planned for in-service teachers.

BNL's Educational Outreach and Resource Programs: These programs support students, teachers, schools, and faculty by offering activities, resources, and opportunities based on the BNL experience. The Laboratory collaborates with many local pre-college educational organizations, conducts workshops for teachers, offers special student events, and provides technical assistance to school districts, largely through voluntary efforts, and cooperation among BNL organizations. These efforts include the following: a Maglev Train Contest; Bridge Building Contest; Science and Society Essay Contest; an Elementary School Science Fair; assistance for schools participating in a national robotics contest; museum programs such as Magnets to Go; an Energy and Environmental Science Summer Camp for elementary school students. In 2003, BNL plans to hold a regional Science Bowl, and arrange an online science expo for middle and high school students and a crystal-growing contest in collaboration with scientists from the National Synchrotron Light Source.

In our educational program we use technology to provide outreach and resources to schools, students, and teachers. The education program's web site was redesigned and more information and resources will be made available. Databases and forms were created, allowing online registration for events and programs. A team of scientists, high school science teachers, high school, undergraduate, and graduate students is developing the Online Classroom Project in collaboration with a team from the Joint Institute for Nuclear Research in Russia. Its goal is to bring the scientific research of the Laboratory to high school students and teachers. In 2002, the focus was on the Relativistic Heavy Ion Collider (RHIC). The project team developed interactive multimedia learning activities related to the science of RHIC and lesson plans and guidance for physics teachers to teach topics related to particle and nuclear physics. In the future, online learning and lesson plans related to the Laboratory's major research areas will be available on the Online Classroom. These outreach efforts reach hundreds of teachers and parents and over one thousand students annually.

Undergraduate Programs will remain a principal focus of the DOE-supported activities in the coming years. Larger numbers of pre-service teachers are participating and this will require additional funding. The DOE also is supporting Faculty and Student Teams and in the future, a major effort will be made to locate university faculty and students who would be interested in collaborating with BNL scientists. There is great demand for undergraduate student interns at the Laboratory and the increased numbers of students will require additional administrative help and more facilities (e.g., classroom, storage, and computer laboratory space).

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We hope to expand our Teacher Enhancement Programs with support from the DOE and other agencies, such as the NSF Math and Science Partnership grants. DOE funding may soon become available for TRAC (an in-service teacher program that was extremely successful in the past).

In addition, the expansion of the DOE's support for grades K-12 programs will increase the opportunity for students to experience science at BNL. These programs currently are funded through the Laboratory's overhead funds and include programs in the Science Museum, outreach programs to schools and libraries, and tours of BNL facilities for high school groups.

In the coming years, the Educational Programs will expand to provide greater support to the scientific mission of the Laboratory. For example, we will improve the matching of students with mentors, and solicit frequent feedback, so that all students and mentors benefit from the internship experience. OEP staff will help scientific staff add educational components to NSF and NIH science grants. Staff will help facilitate educational programs and activities to free up the scientists' time. Eventually, the Office of Educational Programs will become the focus and clearinghouse for all educational programs, activities, and events at the lab. This will require additional resources but it also will bring great benefits such as saving money due to less duplication of effort, and greater opportunities for securing external funding for educational programs. We plan to continue to harness the tremendous resources of the Laboratory to help prepare the nation's future generations of scientists and engineers. At the same time, continuous efforts will be made to improve the science literacy of all students and teachers to help ensure that the value of basic and applied scientific research is understood and appreciated.

Future Program: The Laboratory will continue to align its educational programs to support more strongly the Laboratory's objectives. All of the following near-term objectives will be linked to the Laboratory's scientific research programs:

- Establish an advisory council consisting of BNL's senior scientific management and external educators.
- Continue to improve the three primary undergraduate programs, ERULF, CCI, and PST.
- Develop flexible strategies for extending the ERULF model to continue building collaborations with partnership organizations including opportunities for part-time semester co-op students, cost-sharing arrangements with programs such as NSF's LSAMP and CETP, Faculty and Student Teams (FaST) projects, and joint appointments through local industry.
- Bring science teacher education back by restoring the TRAC program. Under this program, in-service teachers come to the Laboratory during the summer to do research with mentors.
- Develop courses and workshops related to the scientific research at the Laboratory for in-service teachers.
- Maintain and enhance the pre-college science education programs and activities that have proven so successful; the Minority High School Apprenticeship Program, the Community Summer Science Program, the Bridge Building Contest, the Maglev Train Contest, the Elementary School Science Fair, and the Science and Society Essay Contest.
- Continue the Online Classroom Project and focus on a different area of scientific research each year. Develop resources for students and teachers related to scientific research at the Laboratory and place them on the web.
- In the future, hold an Online Science Expo for secondary school students where they will exhibit science research projects online.

- Enhance the Academic Year High School Research Program that matches secondary students with BNL mentors for various activities, such as to answer science questions, and to mentor students on science research projects, e.g., Intel projects, and science fair projects.
- Develop a Secondary School Outreach Program to reach out to local middle and high schools using the science of BNL.
- Hold the DOE Senior and Junior Science Bowl, important nationally recognized activities.
- Design an annual Crystal Growing Contest with NSLS for local students.
- Expand informal opportunities in science education at the Laboratory through the Science Museum. A new location for the museum will be needed in the future to accommodate the return of exhibits on loan, and new exhibits and programs aimed at secondary and college level students. New technology, such as wireless networks, will be introduced into the museum exhibits to present students with the best learning opportunities possible.
- Create an outdoor educational science park that shows the bubble chambers and other large historical scientific apparatus.
- Enhance the facilities of the Science Education Center by improving the computer facilities, the library, and classrooms to make it a place where more students and their mentors can gather.
- Raise the local and national profile of the Office of Educational Programs through a focused program of science education research. Educational programs will be evaluated systematically and the results submitted to academic journals and presented at conferences. Collaboration with science departments will take place more frequently. The Office of Educational Programs will help develop education components of science grants.

5.3 Energy Resource Mission (EE/FE/NE) - Energy Technologies

BNL performs R&D related to the DOE's Energy Resource Mission to provide clean, sustainable energy. The Laboratory's activities focus on basic and applied research, systems analysis, technology development, and transfer to industry of work and technologies that offer innovative solutions to some of the most important energy challenges in the world. On-going projects include proliferation resistant nuclear reactor designs, energy/economic modeling, energy infrastructure reliability, and energy production, transmission, and storage, including fuel cells and batteries.

The DOE's Offices of Energy Efficiency and Renewable Energy (EERE), Fossil Energy (FE), and Nuclear Energy Science and Technology (NEST) support the Laboratory's role in the DOE Energy Resource mission with some funding from other offices within DOE, such as the Office of Policy. In addition, the DOE's Basic Energy Science Program, described previously, sponsors much of the underlying basic research.

BNL has several local, national, and international energy R&D partnerships that support continued U.S. leadership in the energy field. This work supports the programs of the DOE and NRC, EPA, New York State, and private industry.

5.3.1 Energy Efficiency and Renewable Energy (EE)

Present Program: BNL research supports the strategic objective to reduce the intensity of oil and energy use by developing more efficient and nonpolluting heating systems, as well as by improving the distribution and use of energy in buildings. Researchers are developing advanced low NO_x oil burner technologies for homes and commercial buildings. Flame quality indicators developed at BNL are licensed and are becoming available commercially. BNL is involved with large-scale field tests of this technology, which was named by the DOE as one of the Energy 100 technologies.

Researchers also are developing standards for ultra-low sulfur fuel for home heating. This fuel will significantly reduce emissions from home heating systems and increase efficiency by reducing fouling in boilers. A large-scale field test of this work is in progress. Ultra-low sulfur fuels enable the use of very high-efficiency condensing boilers and BNL is testing concept systems. We also conduct programs in cooperation with the New York State Energy Research and Development Agency.

BNL continues research on corrosion resistant materials and cements for reducing costs associated with geothermal energy. During this past year, researchers focused on corrosion testing of NiCrMo alloys, evaluating coatings and mortars for resistance to sulfur oxidizing bacteria, numerical modeling of remediated wells, non-destructive test methods, and field testing, in collaboration with NREL. This work will continue into next fiscal year.

Scientists in BNL's programs on Natural Gas Storage Systems for the DOE's Office of Energy Efficiency and Renewable Energy, work with U.S. industry to demonstrate systems that will significantly reduce costs for producing and storing liquefied natural gas. This includes assessing the production of Liquid Natural Gas from landfills, developing state-of-the-art storage tanks and refueling facilities, designing novel cryogenic fuel delivery systems, and developing strategies for market end-use. This group also is working on hydrogen storage technologies.

Scientists are developing battery materials for hybrid and electric vehicles that are not constrained by the availability of advanced cost-effective materials, focusing on cathodes for high-rate lithium ion batteries. Work continues on novel methods to make new fuel cell electrocatalysts that substantially reduce the platinum requirements for fuel cells. These programs use the National Synchrotron Light Source for material characterization.

BNL will continue research on the material properties of high temperature superconductors. This research, which focuses on their manufacture and application, makes extensive use of our Transmission Electron Microscope (TEM) facility.

In support of the strategic objective to provide national and international energy data and analysis, BNL continues to develop and apply the MARKAL-MACRO computer code, a technology specific, data-rich optimization model that provides least-cost energy system solutions under specified constraints to support policy and planning decisions. MARKAL-MACRO and its associated databases and methods evaluate energy source uses on both environmental and micro/macro economic scales. It can answer specific questions in conjunction with other models, such as air quality dispersion models and Geographic Information Systems (GIS) representations. Some major projects include work with Hong Kong, and a new initiative for the Central American States and Taiwan in which we will use MARKAL-MACRO models to evaluate Clean Development Mechanisms in support of the Kyoto Protocols. EPA Region 2 co-sponsors some of this research.

The Energy Information Agency (EIA) selected MARKAL-MACRO as the modeling tool for the next world energy outlook report. BNL is working with the EIA to develop a world model for their use. We also are developing hemispheric models for the DOE and EPA.

Future Program: BNL will continue to place increasing emphasis on combined cooling, heating, and power technologies that offer substantial gains in efficiency. At present, we are participating in testing the performance of a gas-fired micro-turbine power generator, fuel cells, and an oil-fired microturbine.

Recently, the BNL oil research program was transferred to the DOE's Office of Power Systems, Building Cooling, Heating, and Power (BCHP) program, where there is strong interest in renewed emphasis on oil R&D for building, cooling, heating, and power applications. This DOE Office challenged BNL and the industry to prepare a comprehensive five-year plan that would offer homeowners clear benefits through developing advanced oil combustion technologies. BNL coordinated the development of this plan that proposes to commercialize low NO_x heating burners and very high efficiency heating systems. The program also will promote the use of better quality petroleum fuels as well as domestic biofuels.

BNL is developing a program with Consolidated Edison of New York to examine critical infrastructure issues in the electric grid. A parallel effort, funded under the LDRD program will develop new probabilistic based techniques to analyze failures in electric systems.

5.3.1.1 Energy Efficiency and Renewable Energy Initiatives

The Laboratory is undertaking a major initiative to support the strategic goal of reducing energy use. Specifically, the Laboratory will expand its programs in renewable energy and energy efficiency, initially in two thrust areas:

Wind Power: Interest in wind energy is growing rapidly with the urgency for alternative energy resources. This interest includes installing both land and offshore wind turbines. Implementation of large-scale wind turbines requires solving unique problems of system dynamics and foundations. BNL proposes developing an engineering capability in this area by combining knowledge from previous research in computational mechanics and materials engineering. The objectives are to establish a methodology for evaluating the dynamic response of large wind turbine systems and to evaluate alternative foundation materials. The key element is that turbine-tower-foundation systems will be treated computationally as a whole, rather than as separate components. The computational methodology developed under this project to conduct dynamic analysis of the integrated system will represent a significant technical advancement and may lead to a commercially attractive software package. Alternative foundation materials will be investigated including high fly ash content concrete and fiber reinforced concrete, the use of which is a new approach with great potential for improving the economics of wind energy.

Distributed Power: Distributed power has the potential for increased reliability and efficiency that result from reduced transmission power losses and the potential ability to use waste heat. It also offers an avenue for the practical use of renewable technologies, such as photovoltaics and geothermal energy. However, numerous challenges must be met before the potential can be realized. BNL is working on standards for local interconnected microgrids and is developing reliability management tools.

5.3.2 Fossil Energy (FE)

Present Program: The Laboratory has several programs to develop the next generation options for producing, transmitting, storing, and using fossil fuels. Several could lead to significant reductions in greenhouse gas emissions. Key projects include fuel cells, thermophotovoltaic power generation, and distributed energy systems. Our work includes developing advanced materials that are needed to take full advantage of available domestic energy supplies, sulfur removal technologies, biochemical upgrading to increase available fossil fuel products, and natural gas storage systems.

In FY 2001, DOE began a new initiative to harvest the vast quantities of methane existing as hydrates on the ocean floor and in permafrost. The first phase concentrated on establishing the fundamental properties of methane hydrates that will ensure the safe production of methane by 2015. BNL has strong expertise in structural studies of clathrate hydrates and will team with other national laboratories in applying it. In addition, we are pursuing research in the kinetics of transformation and the application of BNL's tracer technologies to the safety and stability of methane hydrate production.

Thermophotovoltaics (TPV) technology is used to generate electric power from a hot surface using photocells. BNL is part of an industrial team developing a 500-Watt, oil-fired portable generator for the U.S. Army. We are working with another industry team to develop non-military applications, such as hybrid solar/gas-fired TPV cogeneration, and self-powered residential heating appliances.

Future Program: The Department of Energy's goal is to ensure reliable, clean, and diverse supplies of domestic fuels**.** We will continue our program on deep sulfur removal for liquid fuels, including research on biochemical upgrading of oils and other petroleum products; we have selected several bacteria strains to test for desulfurization, denitrification, and hydrocarbon redistribution.

We will expand our work to develop techniques for converting liquid fuels on a micro-scale for multiple purposes. Microcombustion will be a major area into which we will extend our small-scale burner technology. We will begin research on advanced gasifier technology for use in distributed power sources.

5.3.2.1 Fossil Energy Initiatives

The Laboratory developed an advanced fuels initiative to support the DOE's objectives in energy resources. The initiative, in collaboration with SUNY-Stony Brook, initially will have two main thrusts:

Natural Gas to Liquids: Vast natural gas reserves remain unrecovered due to the high cost of access to markets. Catalytic and chemical processing to convert this gas to liquid fuels offers the potential to provide a large resource of ultra-clean liquid fuels for diesel applications. Over the last decade, BNL built an international reputation in Liquid Phase Low Temperature (LPLT) methane conversions. Our initial focus is on developing advanced, nanosized metal catalyst systems for selective hydrocarbon production.

Oil and Gas Processing: The goal of this DOE program is to develop new processing technologies that can produce economic higher quality end products and handle lower quality feedstocks. BNL is pursuing novel techniques for removing sulfur, building on our ongoing work in bioprocesses for upgrading crude oil.

5.3.3 Nuclear Energy (NE)

Present Program: BNL's core competencies are fully aligned with the DOE's Office of Nuclear Energy, Science and Technology's (NE), four major research initiatives: the Advanced Accelerator Applications (AAA) program; the Nuclear Energy Research Initiative (NERI); the Generation-IV Advanced Reactors; and the Nuclear Energy Plant Optimization (NEPO).

The AAA program grew from a merger of the Accelerator Production of Tritium (APT) and Accelerator Transmutation of Waste (ATW) programs. The DOE//NE manages the AAA program, which includes BNL, Los Alamos, Argonne, Oak Ridge, other national labs, several major universities, and appropriate industrial groups. BNL was involved in the APT program since the late 1980s and was a member of the Steering Committee that developed the ATW R&D Roadmap in FY 1999. BNL continues to support spallation target development and sub-critical multiplier design and analyses. BNL also is involved in examining light-water reactor based options for transmutation.

Under the first NERI competition (FY 1999), BNL received funds for two projects on proliferation resistant reactor designs. In FY 2000, an additional project was funded that examines the application of the thorium cycle to existing reactors to enhance proliferation resistance and waste characteristics. In FY2001-2002, BNL partnered with Argonne National Laboratory in the successful NERI and I-NERI (with France) proposals exploring options for gas-cooled fast reactors.

The DOE/NE recently completed a Generation IV Nuclear Energy System Roadmap study; BNL was a member of the Technical Working Group considering options for water-cooled reactors.

The DOE and the Electric Power Research Institute are developing joint NEPO programs to pursue technologies that foster life-extension and optimize electrical generation from existing power plants. This could reduce global carbon emissions by extending the operation of existing light water reactors beyond their license period. Under this program, BNL is examining advanced designs for the control rooms of nuclear power plants, in collaboration with private industry.

Future Program: BNL will expand its work on proliferation resistant reactors in an international collaboration with Russian research institutions and U.S. industry. We will continue to support the accelerator applications research of the DOE, and will work with the Center for Data Intensive Computing to expand its capabilities in computational fluid dynamics for all energy resource applications.

5.3.3.1 Nuclear Energy Initiatives

The Laboratory continues to develop programs that support the DOE's strategic objective to expand the capability of nuclear energy to contribute to the Nation's energy needs. In particular, we are expanding our research programs in accelerator applications, human factors, and the disposition of plutonium.

5.4 National Security Mission (NN)

BNL does not have a weapons development mission, rather, our scientists work on U.S. domestic and international programs in nonproliferation and national security. The focus areas are the following:

- nuclear safeguards and chemical/biological/nuclear arms control verification and transparency,
- security-related environmental threat reduction,
- Russian fissile materials protection, control and accounting, and
- technical support to the International Atomic Energy Agency on safeguards (Work For Others).
- technology development and deployment to benefit U.S. Homeland Security initiatives.

5.4.1 Safeguards and Arms Control Verification and Transparency

Present Program: BNL performs analyses, conducts research and development, provides technical support to U.S. programs and policymakers, and builds prototype instruments and systems (hardware and software). These activities further U.S. interests in nuclear materials safeguards and security, verification and transparency, nonproliferation of weapons of mass destruction, and nuclear security-related infrastructure protection. Currently, we support both the DOE and the International Atomic Energy Agency (IAEA) in implementing "integrated safeguards systems" that incorporate traditional Nonproliferation Treaty safeguards with the new Strengthened Safeguards System, especially the provisions of the Additional Protocol.

A member of the BNL technical staff serves as a "transparency monitor" under the US/Russian Federation Highly-Enriched Uranium Purchase Agreement. BNL successfully completed high-resolution gamma-ray spectroscopy measurements to determine the radiation signatures of U.S. nuclear weapons and components. For domestic safeguards, the DOE accepted the methodology developed by BNL to confirm the presence of highly enriched uranium in warheads returned from the DOD. In addition, staff members participate in the Integrated Technology Development Plan that coordinates the work of the DOE and DOD in designing, testing, and authenticating instruments for monitoring international arms control treaties.

Future Program: During the next two years, BNL will play a more significant role in designing, developing, and testing nuclear warhead dismantlement transparency systems by collaborating with scientists from Russian institutes. We also expect to participate in developing advanced nuclear detectors and measurement systems with special capabilities for dealing with U.S. safeguards and arms control requirements, including

- γ-ray spectrometry at room temperature with resolution adequate to distinguish between plutonium and highly enriched uranium and other non-strategic radioactive materials, and,
- a neutron imaging system for locating and measuring Special Nuclear Material "holdup" in process lines, and long range detection of nuclear devices improvised by terrorists.

We also will work to reconstitute our R&D and technical support role in U.S. domestic safeguards, for the DOE's Office of Safeguards and Security, and with the newly formed Office of Plutonium, Uranium, and Special Nuclear Material Inventory.

5.4.2 Environmental Threat Reduction

Present Program: This program incorporates environmentally oriented components into nuclear, chemical, and biological safeguards, nonproliferation programs, and weapons dismantlement programs. We also work to ensure that the knowledge and skills possessed by former weapons scientists are refocused on civilian activities with an environmental orientation.

In FY 01, under the Arctic Military Environmental Cooperation Program (AMEC) funded by the DOE, DOD, and EPA and the Murmansk Initiative funded by EPA, BNL helped the Russian Ministries of Defense and Atomic Energy install technologies and processes to more safely manage nuclear wastes produced during the dismantlement of Russian nuclear-powered ballistic missile launching submarines. Of special interest was the installation of an automated radiation measurement system at a Russian naval shipyard. Under the DOE Nuclear Cities Program, BNL is helping develop energy and environmental projects in the Russian Closed Cities of Snezhinsk, Sarov and Zheleznogorsk. Under joint sponsorship of NN-24 and NN-45, we are leading an effort to explore the feasibility of using a Russian designed spent nuclear fuel cask to transport materials from Russia, Former Soviet Union States, and Taiwanese reactors. BNL also provides technical support to the U.S. Delegation to the IAEA's Contact Expert Group (CEG) whose objective is to focus international efforts on problems with Russian radioactive waste management. In this context, BNL helped draft a report to the U.S. Congress, in response to Public Law 106-255: Cross-Border Cooperation and Environmental Safety in Northern Europe Act of 2000, on the threat presented by RF maritime reactors.

Future Program: We hope to expand the Nuclear Cities concept to include regions of Russia where the Russian Northern and Pacific nuclear naval fleets operate; the objective of this national security program is to reduce the proliferation threat presented by underemployed or unemployed Russian naval shipyard personnel. BNL hopes to assist the DOE and NNSA to develop and implement a program that responds to the threats presented by Russian maritime reactors and spent nuclear fuel.

5.4.3 Russian Nuclear Materials Protection, Control and Accounting (MPC&A)

Present Program: Since 1994, Brookhaven has been involved in non-proliferation programs at Russian facilities, playing a leading or supporting role in the following areas of the MPC&A Program:

- Introduction of technologies to measure very precisely bulk nuclear materials, both liquid and solid, during storage and processing operations.
- Development and implementation of comprehensive plans for physical inventory statistical sampling, measurement requirements, and performance procedures.
- Use of measurement control techniques.
- Support to Minatom and Gosatomnadzor to develop regulatory documents for nuclear materials protection, control, and accounting in Russian facilities.

The first of these activities provided unprecedented access to the largest of the Russian production facilities, the Siberian Chemical Combine, Mayak Production Association, and the Mining and Chemical Combine.

Another important program activity is the Material Consolidation and Conversion (MCC) Project whose main objective is to consolidate highly enriched uranium (HEU) in fewer buildings and at fewer sites in Russia, and, where possible, eliminate HEU as a proliferation concern by converting it to low-enriched uranium (LEU). Brookhaven is heavily involved in the MCC project and is collaborating with two nuclear facilities in Russia to have them convert HEU to LEU.

As upgrades are completed at some Russian sites, the MPC&A Program examined the need for operational inspection and verification of Russian MPC&A systems funded by the DOE. In February 2001, the General Accounting Office (GAO) recommended that the administrator of the National Nuclear Security Administration "Develop a system, in cooperation with the Russian government, to monitor, on a long-term basis, the security systems installed at the Russian sites to ensure that they continue to detect, delay, and respond to attempts to steal nuclear material." In response, Brookhaven was requested in May 2001 to perform a small pilot project to install an MPC&A operations monitoring system at a Russian nuclear site. This pilot application allowed us to evaluate the feasibility of how such a system might address, at least in part, the GAO recommendation.

The pilot project for monitoring the operation of both MC&A and physical protection systems was successfully completed during the latter part of FY 2001. As a result, the decision was made to install similar systems at as many sites as possible during FY 2002. All of these MPC&A projects are expected to continue into FY 2003, and beyond.

A BNL scientist leads the Technical Survey Team (TST), a group of experts who provide top-level technical review, strategic and program-related advice, and recommendations to the DOE/HQ on all aspects (and projects) under the MPC&A Program. The TST will play an expanding role in influencing the future direction of the multiyear MPC&A Program activities in Russia. In a new activity, BNL is developing an analytical model that will use information in the database to estimate the reduction, in terms of relative risk, associated with implementing MPC&A upgrades.

Future Program: BNL will continue to support all of the aspects of the MPC&A Program described above. In addition, we will assume the leadership of the MPC&A Awareness Project that will address the need to ensure that MPC&A is fully integrated into the institutional mission of the Russian sites, government ministries, and public awareness. BNL also expects to assist the Russians in conducting initial comprehensive physical inventories and material balances on some of their very large uranium and plutonium processing operations. This work brings together all the MPC&A upgrades introduced at the facilities, and provide a good quantitative assessment of the improvements in accounting for nuclear materials. Once it is completed, the program's emphasis will be directed toward gaining assurances that the Russians continue to implement, and can sustain, the upgrades.

5.4.4 BNL Urban Anti-Terrorism Support Organization

The Brookhaven National Laboratory – Urban Anti-Terrorism Technical Support Organization (BNL TSO) conducts applied research, performs technology demonstrations, and consults with and advises Federal/State/City officials on approaches for managing the consequences of terrorist attacks in urban centers involving biological, chemical and radiological weapons or agents. The BNL TSO began work with the Battery Park City Authority and the New York City Department of Health, which complements and expands the support to Federal/State/City authorities that BNL now provides for radiological events in the entire Northeast. BNL is seeking to significantly increase the activities of the Urban Anti-Terrorism TSO to develop science-based approaches for responding to terrorist attacks in urban settings and/or reducing the consequences. BNL's technical/scientific support will be focused in three interrelated areas that use the Laboratory's established expertise and capabilities: Risk Analysis, Advanced Sensors, and Port Security.

Risk Analysis: Brookhaven has an international reputation in both qualitative and quantitative risk assessments. This reputation is based on analyses of risks presented by (1) the diversion of fissile materials in the U.S. and the former Soviet Union, and, (2) commercial nuclear power plants. This expertise will be applied to advance the state-of-the-art in risk analysis for biological, chemical, and radiological events in urban settings. Working in close collaboration with Federal, NY State and NY City agencies, current risk assessment models will be reviewed to determine where methodology must be improved. Risk models that focus on threat characterization, vulnerability assessments, scenario development, and response strategies will be developed for NY City and other urban centers. The results will be used to identify facilities that are vulnerable to attacks, and risk reduction strategies that should be implemented to reduce the consequences.

Advanced Sensors: Brookhaven organized several Long Island institutions and organizations that are interested in, and capable of, contributing to the development of advanced sensor technology and systems that will enhance our ability to detect and respond to future acts of terrorism. BNL's partners include SUNY-Stony Brook, Symbol Technologies, Northrup Grumman, and EDO Corporation. These organizations propose creating a network of sensors around the NYC metropolitan area that could detect minute amounts of biological, chemical, and radiological materials, as well as conventional explosives. This network would alert a data center by wireless technology, and the data would be relayed to emergency personnel.

Port Security: Brookhaven is working with Federal, State, and local governmental agencies to identify vulnerabilities in port security and to rapidly deploy available technologies that will assist in securing marine port facilities from terrorist acts. Brookhaven also is focusing research and development programs in the following areas to enhance the security of port facilities:

- Non-intrusive detection and inspection technologies for standoff detection of improvised nuclear weapons, radiation dispersal devices (dirty bombs), chemical agents, biological agents, and explosives in cargo containers.
- Hand-held monitoring equipment to permit close search of material revealed by standoff or bulk detectors.
- Improved tags and seals specifically designed for shipping containers, ships, trains, trucks, and other conveyances.
- Data visualization and mining, and data imaging systems to permit rapid assessment by port security personnel.
- Response tools to mitigate the consequences of terrorist acts, disable or neutralize terrorist weapons or actions, and identify and collect forensic evidence.

Brookhaven's work on port security focuses on weapons of mass destruction, including nuclear, chemical, biological and explosive threats, and particularly emphasizes reducing the risks of terrorist actions, securing personnel safety, maintaining free flow of commerce, and managing the consequences of terrorist acts.

5.5 Environmental Quality Mission (EM, NP, KP)

Present Program: The Environmental Quality Mission at BNL is dominated by work to remediate the site, decontaminate and decommission the Brookhaven Graphite Research Reactor, and support Waste Management Operations. The DOE's Office of Environmental Management supports the remediation programs. BNL is using an innovative tracer technology and three-dimensional visualization techniques to accelerate the characterization of structures that are part of the Brookhaven Graphite Research Reactor Decommissioning Project. The Office of Science Nuclear Physics program provides support for Waste Management Operations.

The DOE's Office of Biological and Environmental Research funds research programs related to their Environmental Quality Mission. Researchers seek to understand the basic biochemical mechanisms involved in the microbial transformations of organic complexing agents of radionuclides and toxic metals commonly present in DOE wastes. One goal is to determine how microbes can be used to reduce the concentration of environmental radionuclides and heavy metals. Remediating marine sediments contaminated by radionuclides and toxic metals is a special challenge, and basic research on the transformation of heavy metal contaminants in sulfate-reducing sub-surface environments will continue.

Future Program: We envision advances leading to technologies that will aid in environmental restoration and long-term management of the DOE's contaminated sites. Brookhaven has a long history in bioremediation and polymer encapsulation and holds patents in both areas. Strategic objectives include hiring staff to more effectively use BNL's unique research facilities to understand remediation processes, and aligning research programs and technologies to the sponsors' needs. A technology is being developed for the *in situ* treatment of mercury-contaminated soils; it could be used effectively at several sites in the DOE complex.

5.6 Major DOE Partnerships

Relativistic Heavy Ion Collider (RHIC): RHIC, designed to create and explore a new state of matter, the "quark-gluon plasma", and to be the world's highest energy source of polarized proton-proton collisions, represents a major collaborative effort among the U.S. DOE Laboratories, U.S. universities, and worldwide scientific communities. The four RHIC detectors, BRAHMS, PHENIX, PHOBOS, and STAR, involve more than 1000 scientists from five DOE National Laboratories, 40 U.S. universities, and 50 non-US institutions from 19 different countries. Each collaborating DOE Laboratory, as well as many of the U.S. universities and foreign institutions, contributed to the design and construction of the detectors and are participating in the experimental program that began in 2000.

Large Hadron Collider (LHC): Brookhaven plays an important role for the U.S. in the LHC Project and its subsequent scientific program. BNL is the host laboratory for U.S. participation in the ATLAS detector. The Laboratory manages construction of the U.S. contributions to this detector, including the computing infrastructure. BNL also will provide operations management and oversight for all U.S. scientists participating in the ATLAS experiment and will operate the BNL-located Tier-1 Computing Center, positioning U.S. scientists for effective collaboration in the physics research program. BNL collaborates with two other DOE laboratories (ANL and LBNL) and with research teams from about 29 universities in the U.S., and is a member of a three-laboratory team (with Fermilab and LBNL) that manages the U.S. contributions to the accelerator part of the LHC Project. BNL will test all the LHC's superconducting cable and produce a set of RHIC-type superconducting magnets for the machine lattice. BNL also contributes important expertise to the accelerator physics effort for the LHC.

Muon Collider/Storage Ring: Three potential technologies are possible successors to the LHC: linear electron-positron colliders, muon colliders, and very large hadron colliders. The world's high-energy physics community will vigorously pursue R&D to refine the technical merits of each and to characterize their costs and scientific applicability to the next generation of research in particle and nuclear physics. BNL is a key member of the multi-institution Muon Collider Collaboration, initiated in 1997. Its goals are to explore the feasibility of a practical multi-TeV collider and a multi-GeV muon storage ring for neutrino physics. Computer calculations and experimental tests of muon collider concepts are a central component of this R&D program. BNL is consolidating the group's efforts in a directed program of exploratory R&D, employing a project management approach. Members of the Muon Collaboration include nine national laboratories and 17 university research groups.

Spallation Neutron Source (SNS): The Spallation Neutron Source is a 1 GeV, 2 MW, proton facility that will be built at the Oak Ridge National Laboratory. BNL is a member of a six Laboratory consortium (with Argonne National Laboratory, Los Alamos National Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, and Thomas Jefferson National Accelerator Facility) that will construct the world's most powerful accelerator-based neutron source for the DOE's Basic Energy Sciences program. BNL's responsibility is to design, construct, and commission the 1 GeV accumulator ring, and the beam transports from the linac to the ring, and from the ring to the target station.

D0 Collaboration: BNL helped design and build Fermilab's D0 detector, and for many years has been part of a key user-group there. This very productive research continues. The announcement of the discovery of the top quark by the D0 Collaboration, several years ago, demonstrates this productivity; BNL's physicists played a leading role in that very important successful search. BNL provided new apparatus, the Preshower Detector, to upgrade D0. The upgrade was completed, and data acquisition began in 2001. BNL will be a leading participant in a multi-year experimental search for the Higgs boson and for physics beyond the Standard Model.

Solar Neutrino Collaboration: BNL has been part of the SNO Collaboration since 1996, operating the Sudbury Neutrino Observatory in Canada. SNO is the premier solar neutrino detector currently funded by the DOE. Participating institutions represent Canada, the U.S., and the UK. BNL also is a charter member of the recently formed LENS Collaboration, which is doing R&D on a new Low Energy Neutrino Spectrometer, along with institutions from the U.S., France, Germany, Italy, Japan, and Russia.

Other Collaborations in High Energy and Nuclear Physics: BNL's nuclear physicists are involved in several upcoming experiments at the Thomas Jefferson National Accelerator Facility (TJNAF) and will continue to be in future years. BNL's nuclear chemists have contributed significantly to solar-neutrino experiments and will continue to do so for the foreseeable future.

Global Climate Change and Carbon Management: BNL participates in the multi-laboratory and university collaborations on global climate change and carbon management protocols. BNL leads the FACE program and has a principal role in the ARM program. We are working closely with Pacific Northwest National Laboratory and Oak Ridge National Laboratory to integrate the various tasks in the DOE’s climate change response, and to link with other agency participants from the National Oceanographic and Atmospheric Agency and the National Space and Aeronautics Agency. National coordination and integration is essential for developing a unified research program on climate change.

International Nuclear Safety Program: BNL is a member of the national laboratory team headed by Pacific Northwest National Laboratory to ensure the continued safety and orderly shutdown of the Former Soviet States’ reactors. The team corrects major safety deficiencies and establishes nuclear safety infrastructures that will be self-sustaining. More than 150 joint projects were begun at nuclear installations. BNL’s focus will continue to be on training, simulator development, safety system upgrades, fire hazard analysis, and technology transfer.

Initiatives for Proliferation Prevention: BNL is an active participant with other multi-program laboratories and the Kansas City Plant in the Initiatives for Proliferation Prevention Program (IPP). The program’s goal is to engage scientists and engineers with experience in developing weapons of mass destruction (WMD) in the Newly Independent States (NIS) of the Former Soviet Union, to develop technologies appropriate for commercialization, and to create long-term employment. The program seeks to develop partnerships between NIS scientists, BNL, and U.S. businesses in non-weapons related research and commercial activities. BNL initiated over fifty individual projects that reflect our overall research portfolio. The projects span topics such as high-energy physics, reactors, waste management, smart video, software development, and biotechnology. BNL will expand the existing program by developing additional Cooperative Research and Development Agreements with U.S. industry, make use of our interactions with LISTNET to engage local software development companies in this program, and extend efforts to recruit businesses from New York State and the northeast to participate in IPP. We also will take part in the Nuclear Cities Initiative that seeks to create jobs by providing commercial opportunities for former weapons scientists in the ten closed cities of the Russian Federation.

5.7 Laboratory Directed Research and Development (LDRD)

The purpose of the LDRD program is to encourage and support the development of new ideas that could lead to new programs, projects, and directions. The LDRD Program focuses on early exploration and exploitation of creative and innovative concepts that enhance the Laboratory’s ability to carry out its current and future mission objectives in line with the goals of the Department of Energy. This discretionary research and development tool is an important way of maintaining our scientific excellence. It stimulates the scientific-technological community by fostering new ideas, maintaining staff excellence, and focusing on advancing the national agenda within the overall mission of the DOE. Small projects normally are appropriate candidates for the LDRD Program, ranging from $50,000 to $200,000 per year, with a preference for the smaller ones. They generally are funded for two years with a possible continuation for a third. Typically, they include but are not limited to

- New or unexplored directions at the forefront of basic and applied science and technology for the primary purpose of enriching the laboratory's capabilities.
- Advanced exploration of new hypotheses, new concepts, or innovative approaches to scientific or technical problems.
- Experiments and analyses directed toward "proof of principle" or early determination of the value of new scientific ideas.
- Conceptual and preliminary technical analysis of experimental facilities or devices.

The responsibility for the LDRD program resides with a Scientific Program Director who reports to the Deputy Director for Science and Technology, and coordinates, oversees, and administers the program. A Committee consisting of the Deputy Director, the LDRD Scientific Program Director, all Associate Laboratory Directors, and two senior scientists chosen from the Brookhaven Council review all proposals, obtain additional information deemed necessary, select the projects to be funded, and determine the amount of each award.

The LDRD program is a crucial and indispensable ingredient in promoting the vital mission of BNL as a multidisciplinary laboratory dedicated to the advancement of physics, chemistry, the life sciences, energy and environmental sciences, as well as key technological areas. The LDRD fosters the advancement and full utilization of user facilities. Aside from leading to new or promising programs at the Laboratory and producing especially noteworthy research, the LDRD Program has resulted in numerous publications in various professional and scientific journals, presentations at meetings and forums, and patent applications and patents. The program contributes to educating the nation's future scientists as it supports several post-doctoral fellows. Accordingly, BNL is increasing its relatively modest expenditures for the LDRD Program from its present level of less than two percent of its budget to about four percent (Table 4), still significantly less than the DOE mandated cap of six percent.

Table 4 - Proposed LDRD Funding Levels (In Millions)

Fiscal Year	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Budget	7.0	8.0	9.0*	9.5*	10.0*	11.0*

* Projected

6.0 Work For Others and Technology Transfer

6.1 WFO - Federal Sponsors

Several of our biomedical programs and facilities operate through partnerships with, and funding from, other federal agencies. They include our Imaging and Neuroscience Center, the Scanning Transmission Electron Microscope, and the Structural Biology program at the NSLS. This type of partnership and distributed support is important in advancing science and technology in the national interest.

More than 800 biologists from Brookhaven, other national laboratories, universities, and pharmaceutical companies use nine of the NSLS experimental stations to study biological structures by crystallography. Four are involved directly in a cooperative effort, funded by the DOE OBER and the National Center for Research Resources (NCRR) of the National Institutes of Health (NIH). We call this consortium, which also includes partial participation by members of the NSLS staff, the PX Research Resource, or the PXRR. The total annual budget of approximately $4M supports the activities of twenty workers who provide support to users, maintain the facilities, engage in R&D programs to improve them, and carry out fundamental research on experimental methods and structural biological subjects. A major thrust of the Brookhaven scientists' work, including a collaboration with a fifth facility administered by LANL, is to develop new methods, equipment, and software in structural biology for macromolecular crystallography. This work is improving the effectiveness of the NSLS facilities by standardizing approaches, hardware, software, and techniques. The NCRR funding allowed us to make several important innovations: an on-site technical specialist to support users, 20 hours per day, seven day per week; personnel and facilities for a mail-in data collection service ("FedEx Data"); and, web-based observation of the experiment and the possibility for remote control.

The five structural biology stations are

- X8-C - Operated by a Participating Research Team (PRT) comprised of Los Alamos National Laboratory, NRC Canada, UCLA, Hoffman-La Roche, and the BNL Biology Department.
- X12-B - Operated by a BNL Biology Department PRT.
- X12-C - Operated by a BNL Biology Department PRT.
- X25 - Operated cooperatively by a BNL National Synchrotron Light Source PRT and the Biology Department.
- X26-C - Operated by a PRT comprised of Cold Spring Harbor Laboratory, SUNY Stony Brook, the Georgia Research Alliance, and the BNL Biology Department.

The PXRR is collaborating with The Albert Einstein College of Medicine to construct a new beamline for PX at the NSLS. The beamline will be at position X29, and will be based on a small-gap in-vacuum undulator. Initial funding from the National Institute of General Medical Sciences (NIGMS) allowed construction of most of the components within the synchrotron wall itself. Additional funding from NCRR will be used to build the experimental station. Probably, the NSLS budget will provide the required balance of funding, representing direct support for PX research.

An immediate project to improve the efficiency of the "FedEx" service and the work of some other users is construction of a robotic specimen changer. It will be used first at X12-B and then replicated at X25. This work is a direct collaboration between the NIH and DOE OBER-funded development work at LBL.

Brookhaven National Laboratory

Along with several other centers, BNL is piloting procedures for the cost-effective large-scale determination of protein structures by crystallography. In partnership with Rockefeller University, the Albert Einstein College of Medicine, Cornell Medical School, and Mt. Sinai School of Medicine, BNL recently received an NIH grant to support further development of structural genomics technologies and to establish a pilot structure-production center.

NIH also substantially supports biomedical research through grants to individual investigators. Such grants support work at the Imaging and Neuroscience Center, investigations on DNA damage and repair, protein structure and folding, viral proteases and receptors, and the Lyme disease bacterium. With NIH support, we will collaborate with the Stony Brook University Medical Center on genomic, biochemical, and protein structural analysis of the Lyme disease bacterium and emerging pathogens of regional interest.

The construction and operation of the Booster Applications Facility (BAF) for NASA represents the DOE's ongoing partnership with NASA to provide extraordinary facilities and capabilities for research on issues related to NASA's mission. This is consistent with BNL's goal to provide innovative science, our strategic objective to apply our unique research facilities to issues of human health, and to provide our unique capabilities to assist other national programs.

The goals of NASA and the DOE are the following:

- Use BNL's unique accelerator facilities, such as the Alternating Gradient Synchrotron (AGS) and the Booster, to simulate aspects of the space radiation environment.
- Support investigations of the response of living systems to radiation exposure in space.
- Promote developments in science and technology that meet NASA's requirements for radiation protection in space.

The Booster Applications Facility (BAF) will be a new experimental facility and accelerator that takes advantage of heavy-ion beams from the Brookhaven Alternating Gradient Synchrotron Booster for studies on radiation effects related to the space program. BAF will provide protons and heavy ions (such as Fe, Si, C, Ni, Ar, Au) for space radiobiology studies and radiation effects on microelectronics. It will deliver a complete range of high-atomic number, high-energy heavy ion beams with energies from 40 MeV/A to 1500 MeV/A, depending on the particular ion species. Construction will continue through FY 2002, and the BAF is slated to be fully operational in 2003.

The facility will have laboratories to meet the specific needs of NASA's Space Radiation Health Program (SRHP) and National Space Biomedical Research Institute's (NSBRI's) research programs. The BAF will include laboratories for *in vitro* and *in vivo* experiments, as well as for physics experiments. The experimental facility will be housed in a well-shielded irradiation area and in a support building containing ready-rooms, laboratories, and offices. Other existing on-site facilities, such as extensive tissue culture laboratories and animal handling installations will be used. Dosimetry and local access control will be provided through a local facility control room. The BAF will offer investigators a unique workplace in which they can pursue space radiation research.

The Space Biomedical Research program is a collaborative effort of BNL's Medical, Collider-Accelerator Department, Biology Department, and the Instrumentation Division with Stony Brook University. The program focuses on understanding the biological consequences of long-term space flight.

The National Space Biomedical Research Institute (NSBRI) is a consortium of twelve institutions working to prevent or solve health problems related to long-duration space travel and prolonged exposure to microgravity. BNL is one of those twelve institutions. Our current NSBRI projects focus on the risk assessment and chemoprevention of High-Z, High-Energy (HZE)-induced damage to the central nervous system, development of a heavy-ion microbeam and micron resolution detector for radiation studies, heavy-ion induced cluster DNA damage, and the development of educational programs on space radiation effects.

Since 1995, the National Aeronautic and Space Administration (NASA) also has supported research at BNL's Alternating Gradient Synchrotron (AGS) on the radiobiological effects of high-energy heavy ions. The AGS is the only accelerator in the U.S. able to produce heavy ion beams at energies of interest for space radiobiology. These experiments address the particular problem of exposure to high-energy heavy ion radiation during future long-term deep space flights. The principal objective of this research is to improve our understanding of the biological effects of low fluences of charged particles on living cells and tissues. These experiments continue in collaboration with investigators from universities, national laboratories, and other research institutes from the U.S. and international research community.

We plan to expand our space neuroscience projects beyond the study of the effects of space radiation. Areas of critical interest include the use of state-of-the-art neuroimaging techniques to understand the neurochemical and functional alterations induced by long-term space flight. Of particular interest are sleep disorders and psychosocial problems.

Since BNL has a state-of-art space radiobiology facility on-site, we propose development of a Space Radiobiology Center at the Laboratory in partnership with NASA, NSBRI, and other national and international partners (ISA, NASDA). The center will provide a mechanistic and functional framework for risk analysis and countermeasure development in support of the NASA manned space program. This will enhance our current programs and align them with NASA’s strategic plan.

Brookhaven's capabilities and skills also extend to international work supporting the DOE and its sister agencies in transferring technology to friendly nations. Our near-term focus is the former States of the Soviet Union, specifically in the areas of reactor safety and decommissioning the nuclear navy. BNL supports the EPA's Office of International Affairs and the DOD in several environmental cleanup projects in Kazakstan. Brookhaven's International Safeguards Project Office (ISPO) manages the U.S. Support Program which assists the International Atomic Energy Agency (IAEA) in developing safeguards verification approaches, new measurement and surveillance systems, and integrated safeguards approaches which combine traditional safeguards with new measures. Developing nations are increasingly using our MARKAL-MACRO computer code to help them design energy-efficient infrastructures.

BNL designated growth in our science and technology work for other federal agencies as a goal over the next three to five years. We will meet this goal by increased interdisciplinary research collaborations that will expand our ability to address issues of environmental quality, national energy needs, global security, and human health.

We will continue to seek partnerships with the NIH’s Division of Research Resources and the National Institute of General Medical Sciences (NIGMS) to develop facilities for medical research at the NSLS and increase their usefulness to the wider research community. The NIGMS is exploring ways in which their support can increase the efficiency of, and user access to, the protein-crystallography beamlines. BNL researchers working on these beamlines plan to search for single-nucleotide polymorphisms in human genes that are important for recognizing and repairing DNA damage, starting with the DNA-dependent protein kinase and related genes.

We also will seek increasing support from NASA, NIH, EPA, DOD, and DOT by offering our unique user facilities and expertise. For the DOD, we will expand our work on chemical and biological defenses. For the NIH, we expect greater use of our cancer diagnostic and treatment facilities and expertise. For the EPA, the Corps of Engineers, and the Navy, we are proposing to expand our harbor sediments program in conjunction with Stony Brook University and Battelle-Duxbury. We intend to use our expertise in human factors and risk assessment, combustion and cable test facilities, and the Raman LIDAR system for the Department of Transportation to address aircraft safety and airport security.

Following several years of decline, the work supported by the Nuclear Regulatory Commission at BNL has stabilized. We expect funding to continue at the same or higher level in the future, as new reactor concepts, such as the pebble bed modular reactor, and new fuel concepts, such as high burn-up mixed-oxide fuel, are open to regulatory review. In addition, the introduction of risk informed regulation and the submission of license renewal applications will continue to require BNL's efforts.

6.2 WFO - Non-Federal Sponsors

Historically, sponsored research has been an underused component of the Laboratory's Technology Transfer Program; now, it is an opportunity for future growth. BNL will seek to expand its sponsored research with non-federal entities in areas that are relevant to the DOE's research missions. BNL has many unique capabilities and facilities not available in the private sector that offer opportunities for sponsored research in environmental sciences, energy technologies, materials sciences, and biotechnology.

6.2.1 Private Firms

BNL scientists perform research for several private firms, often taking advantage of BNL's unique facilities. In the past, the majority of BNL's privately funded WFO was in the energy sciences area; however, there is a recent influx of privately funded biomedical research. Current work for private firms includes the following:

- Aerodyne Research Corporation: "Developing a Versatile Aerosol Mass Spectrometer for Organic Aerosol Analysis" (funding from DOE SBIR)
- Airborne Contaminant Systems, Inc.: "Testing of Filtration Efficiency on Device for Removal of Biological/Radiological Hazards Injected into Commercial Air Handling Systems"
- Allergen, Inc.: "Crystallization of Botulinum Neurotoxin Type E Light Chain"
- Eli Lilly & Co.: "Effects of Tomoxetine and Phentermine on [11C]"
- Energy Research Center, Inc.: "New York State Premium Low-Sulfur Fuel Marketplace Demonstration" (funding from the New York State Energy Research and Development Agency)
- Insight Technologies: "Development of a Two-Stage Oil Burner with Wide Hand Tracking Control" (funding from the New York State Energy Research and Development Agency)
- ITT Industries: "Ultraviolet Raman Spectral Signature Acquisition" (funding from U.S. Dept. of Defense (DOD)
- KeySpan Energy Corporation:
  - "Alternative Repair Materials for Restoring Damaged 16 year-old Insulating Polymer Concrete Dike Overlap"
  - "Polymer Grouts and Polymer Composite Liners for Retaining Excavated Wall Foundations"
  - "Recycled Waste-based Cement Composite Materials for Rapid/Permanent Road Restoration and Grout for Soil Stabilization"
- NOCO Energy Corp.: "Low Cost Bioheating Oil Application"

- Raytheon: "Technical Support for FAA Aircraft Wire Degradation Study (Phases II and III)" (funding from the Federal Aviation Administration)
- Structural GenomiX, Inc.: "Center for Structural Genomics" (funding from the National Institutes of Health (NIH))

6.2.2 Non-Profit Organizations/Institutions

The largest segment of our work for non-profit organizations/institutions is in our biomedical research programs. Sponsors in this category use BNL's capabilities in Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI) extensively. Currently work for non-profit organizations/institutions includes the following:

- Battelle Memorial Institute: "Technical Support for BMI Technology Platforms"
- Cooley's Anemia Foundation, Inc.: "A Novel Method to Measure Iron *In Vivo* in the Liver and Heart of Thalassemia Patients"
- Cotton, Inc.: "Genes Controlling Cotton Fiber Properties"
- Houston Advance Research Center: "Quantification of Fugitive Reactive Alkene Emissions from Petrochemical Plants with Perfluorocarbon Tracers"
- National Multiple Sclerosis Society: "Quantitation of Blood-Brain Barrier Permeability in MS Lesion Development"
- National Oilheat Research Alliance: "Maximizing Fuel Performance in Residential Heating Systems"
- National Space Biomedical Research Institute (all work funded by the National Aeronautics and Space Administration (NASA)):
  - "CNS Damage and Countermeasures"
  - "Effect of Deep Space Radiation on Human Hematopoietic Stem Cells"
  - "Heavy Ion Microbeam and Micron Resolution Detector"
  - "Risk Assessment and Chemoprevention of HZE Induced CNS Damage"
- New England Medical Center Hospitals, Inc.: "Selegiline Oxidative Stress and HIV Dementia" (funding from NIH)
- St. Luke's-Roosevelt Hospital Center: "Medical Applications of Precision Neutron Activation" (funding from NIH)
- The Scripps Research Institute: "Methamphetamine and AIDS: Toxic Interactions in Animals" (funding from NIH)

6.2.3 Educational Institutions

BNL's atmospheric chemistry and oceanography programs are extensively involved in sponsored research programs for educational institutions; several leverage the DOE's investments in atmospheric chemistry. Educational institutions also extensively use our capabilities in biomedical research, and PET studies funded by non-federal sponsors have been extremely effective in monitoring the brain's metabolic functions and providing new insight into treating schizophrenia and Alzheimer's disease. Current work for educational institutions includes the following:

- Columbia University: "Influences of Atmospheric Aerosol on Precipitation in the Tropics" (funding from NASA)

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- Cornell University (funding from the New York Dept. of Transportation NYDOT)):
  - “CADD-Based Expert System for Passive Snow Removal”
  - “Tort Database”
- Emory University: “AIDS and Opiates: A Monkey Model” (funding from NIH)
- Georgia Institute of Technology: “Measurement of Particle Chemical Composition During NASA TRACE-P” (funding from NASA)
- New York University School of Medicine: “Clinical Correlates of Longitudinal PET Changes in Alzheimer’s Disease” (funding from NIH)
- Pennsylvania State University: “Development of Cloud Property Retrieval Algorithms at Boundary Facilities” (funding from DOE)
- Polytechnic University: “Stormwater Management Practices Study” (funding from NASA)
- State University of New York System:
  - “A Study of the Outer Shelf, Shelf Break, Front and Slope From Long Term ADCP and Hydrographic Observations from the MV Oleander” (funding from the National Science Foundation (NSF))
  - “New Approach for Assessing Mutagenic Risk of Contaminants in the Long Island Sound (funding from the U.S. Environmental Protection Agency (EPA))
  - “PM2.5 Technology and Characterization Study in N.Y.” (funding from EPA)
  - “Regulation of Tissue Repair” (funding from NIH)
- University of California at San Diego: “The Collection of Shipboard Acoustic Doppler Current Profiler Data During the Shelf Basin Interaction Program” (funding from NSF)
- University of Colorado at Boulder: “Single Molecule Field-Effect Transistor” (funding from DOD)
- University of Connecticut: “Project 2: PET and SPECT Radiotracers for Brain Cannabinoid System” (funding from NIH)
- University of Delaware: “The Impact of Surface Precipitation on Sequestration and Bioavailability of Metals in Soils” (funding from DOD)
- University of Florida: “Catalytic Mechanism of Human Mn Superoxide Dismutase” (funding from NIH)
- University of Rochester: “U.S. Atlas Barrel Cryostat Design and Procurement” (funding from NSF)
- University of Southern California: “Attentional Modulation in Early Sensory Processing” (funding from NIH)
- Woods Hole Oceanographic Institution (funding from NSF):
  - “Development of Perfluorocarbons as Ocean Tracers”
  - “GLOBEC-01: The Physical Oceanography of Georges Bank and its Impact on Biology”
- Yale University:
  - “KOPIO” (funding from NSF)
  - “Rice Functional Genomics: Mapping a Male Sterile Gene” (funding from the U.S. Department of Agriculture)

6.2.4 State Agencies

The majority of funding from state agencies comes from the New York State Energy Research and Development Authority (NYSERDA). Our Combustion Equipment Technology (Oil Heat Research Program) has conducted important research in advanced oil heat technologies for NYSERDA for the past several years, and our success has attracted new sponsors in private industry and non-profit organizations for work in this area. Current work from state agencies includes the following:

- NYSERDA:
  - “High Efficiency, Condensing Heating Appliance Firing Low Sulfur Oil”
  - “Improved Electric Power Efficiency in Heating Equipment”
  - “The Use of Biodiesel Fuel Blends in Space Heating Equipment”
  - “Variable Firing Rate Oil Burner Using Pulsed Fuel Flow Control”
- Texas Natural Resource Conservation Commission: “Analysis of TexAQS 2000 Data”

6.2.5 Foreign Sponsors

BNL’s expertise in conducting risk-assessment studies and other work for the Nuclear Regulatory Commission (NRC) resulted in a significant amount of foreign sponsored research, for which we perform similar studies at foreign nuclear power plants. Current work includes the following:

- ENCONET Consulting (Austria): “Risk-Informed Applications for Nuclear Power Plants”
- Swedish Nuclear Power Inspectorate: “Assistance in Nuclear Power Plant Control Room Modernization”
- Union Fenosa Group (Spain): “Review of CNJC Design Documentation for Proposed Control Room Modification”

6.3 Technology Transfer

A goal of the Laboratory’s Science and Technology Program is to “Add value to the U.S. economy through the development and application of new and improved technologies." BNL’s technology transfer program has two primary objectives; to complement our DOE research mission through involvement in technology transfer projects that enhance our research capabilities; and, to be a resource to U.S. industry, thereby enhancing the competitiveness of U.S. companies in domestic and international markets. BNL uses the following mechanisms in conducting its technology transfer program:

- industry use of Brookhaven's world-class designated user facilities for proprietary or non-proprietary research,
- work for non-federal sponsors (universities, utilities, hospitals, non-profit institutions, and state and local governments),
- collaborative research projects under Cooperative Research and Development Agreements (CRADAs), and
- intellectual property protection and licensing.

The Laboratory’s Office of Intellectual Property and Industrial Partnerships is responsible for BNL’s technology transfer program.

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Under its Prime Contract with the DOE, Brookhaven Science Associates has the right to take title to the technologies invented by Brookhaven employees at the Laboratory, the patents covering them, and to license these patent rights to industry. The following are examples of promising technologies that are available for licensing:

- biological materials and processes, including gene expression systems, DNA-sequencing processes, and recombinant plasmids for encoding restriction enzymes,
- environmental remediation techniques, including materials to encapsulate contaminated wastes,
- radiolabeled materials for diagnostics and therapeutics,
- advanced electrochemical materials for battery components,
- electrocatalysts for fuel cells.

Inventions arising from our biotechnology research programs continue to be of special interest to industry. Our strengths in medical imaging, radiopharmaceuticals, nuclear medicine, molecular genetics, genomics, structural biology, and protein engineering continue to produce new technology that is licensed to industry. Technology based on our T-7 gene expression system continues to evolve, with new patents issued and new commercial licenses granted. At the close of FY 02, there were 133 technologies in BSA's Patent Licensing Portfolio; 51% of these technologies are licensed to industry, and 9.7% of the licensed technologies have been commercialized, with new products based on these technologies now on the market. The net revenue generated by the licensing program, which is re-invested in the Laboratory's research programs, continues to increase each year. At the same time, the licensing program continues to be very cost effective, with the costs of patent prosecution, patent maintenance, and licensing being 23% of the gross revenue in FY 99, 29% in FY 00, 27% in FY 01, and 23% in FY 02 (Licensing Information is provided in Appendix C).

The Laboratory will continue to expand the Intellectual Property Licensing Program to effectively foster the marketing of our new technologies. We will explore the possibilities that computer software, originated at BNL, may have market applications and be appropriate for copyrighting and licensing.

Over the past several years, CRADAs have proven to be a valuable component of BNL's research portfolio. These programs enhance BNL's research capabilities and provide access to industrial expertise and capabilities. CRADA projects have generated new technologies and numerous patents, created new commercial products and processes, and demonstrated the societal relevance and public benefit of the DOE's research.

BNL's participation in CRADAs (further information presented in Appendix C) was funded primarily from the following three sources:

- The DOE's Office of Science Laboratory Technology Research (LTR) Program that in the mid-90s supported most of BNL's CRADA programs, but over the last several years experienced severe cuts in funding,
- The DOE's Initiative for Proliferation Prevention Program for the Newly Independent States of the Former Soviet Union (IPP-NIS), and,
- Industrial partners who fully fund BNL's CRADA research activities.

The DOE's Office of Science Laboratory Technology Research program supports high-risk, multidisciplinary research partnerships to investigate challenging scientific problems whose solutions have promising commercial potential. BNL's strengths in research on electronics/instrumentation, energy, the environment, and biotechnology underpin our participation in this enterprise.

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The instrumentation capabilities at BNL are used in two active CRADAs, funded by LTR, with Long Island companies. In the first, we are working with Advanced Energy Systems to design, fabricate, and test a high duty factor, high brightness, all niobium superconducting RF gun. The second project, with a small Long Island business, Brookhaven Technology Group, is to generate a compact, cost-effective, high-brightness 5 MeV electron gun. Such high-brightness electron beams are needed for high-luminosity electron colliders and efficient short-wavelength Free Electron Lasers.

LTR-funded CRADAs also leverage the DOE's investment in biotechnology research at BNL. BNL and Miravant Medical Technologies are engaged in cooperative research to conduct synchrotron-based structural studies of hydroporphyrin sensitizers for photodynamic therapy of cancer.

The IPP-NIS program supports research partnerships at BNL that take advantage of the research capabilities of established scientific institutions in the NIS, and the commercialization expertise of U.S. industry. The DOE supports the research conducted by BNL and the NIS institute, while our industrial partner supports its own work through a CRADA. BNL is a participant in eight IPP-NIS CRADAs. Examples of these projects include the BNL/Canberra Aquila, Inc. CRADA under which we are working with the General Physics Institute in Russia to develop remote detectors for breath alcohol, and the BNL/MIT CRADA under which we are working with GE's Global Nuclear Fuels and Kaz Atom to develop fuel-processing technologies.

The Laboratory successfully attracted research funding from industry to support research collaborations. BNL is working with Dow Chemical Company to create environmentally beneficial agricultural plants with novel applications for human health and nutrition. We anticipate that through this collaboration, BNL will assist in developing genetically engineered seed crops that can produce oil to replace conventional fuels and petrochemicals. BNL is working with Psimei Pharmaceuticals to develop new boron containing drugs for neutron capture therapy of different malignant tumors.

The Laboratory's work for non-federal sponsors program allows us to carry out research for utilities, universities, non-profit sponsors, and state and local government. We anticipate more interactions with northeast utilities, non-profit foundations, and hospitals.

BNL identified technology transfer as a potential growth area in the Laboratory's overall R&D portfolio. We will continue to vigorously pursue opportunities to expand research partnerships to support the Laboratory's overall strategic plan and to build on recognized research capabilities and our unique scientific facilities.

7.0 Management and Operations Systems

Brookhaven National Laboratory's strategic planning processes align BNL's management and operating systems to support the DOE's national missions and strategic plans. Several systems are central to BNL's ability to meet these challenges. These are described in this section.

BNL implemented an integrated set of non-overlapping management systems that embody the requirements defined by the DOE for Integrated Safety Management (ISM). These systems collectively form the Standards Based Management System (SBMS) – BNL's highest level operating and business processes, defining how work is conducted at the Laboratory. Management System Descriptions identify the processes, standards of performance, external requirements, and the set of Laboratory-wide procedures and guidelines that fulfill the requirements of each system. Tailoring work controls to the hazards ensures that work processes incorporate appropriate environment, safety and health, and quality considerations into each element of BNL's work.

The Laboratory also enhanced the ownership and accountability for ES&H performance. Managers responsible for the work are expected to understand the hazards, establish appropriate controls before work is started, and ensure appropriate control of workplace risks. Field ES&H Subject Matter Experts assist line managers in meeting these responsibilities.

Brookhaven National Laboratory's contract with the DOE is founded on Performance-Based Management to achieve our mutual goals in a changing science and technology environment with increased competition for funds, by institutionalizing modern, effective management practices and business systems. We are making a concerted and focused effort to plan our future and manage our assets. We will accomplish our goals by continually aligning our missions with the DOE's missions and national goals, and by setting an expectation of "excellence in performance" for every employee.

7.1 Human Capital

Our Human Resource goal is to develop, implement, and continually improve personnel programs, processes, and policies that enable the Laboratory to attract, hire, develop, compensate, retain, and reward a highly qualified and diverse workforce. Within that mission, we focus on the following areas:

- Establishing and maintaining a work environment of opportunity and empowerment.
- Pursuing increased employee and leadership effectiveness.
- Capitalizing on, and improving, the diversity of the Laboratory's staff.

A range of programs enhances the Laboratory's attractiveness as an employer. We will enhance opportunities for employees through internal placements, career planning, and training for a wider range of staff in a broad range of relevant areas. Training will be targeted to current and anticipated Laboratory needs. Career development will be expanded, and the scientific career advisory program will be strengthened.

We will continue to review and improve the effectiveness of Human Resource processes, programs, and systems needed to define work, organize staff, and improve work results; this includes making the tools supporting those systems more accessible and usable by employees, primarily through web-based tools, such as the new Human Resources System. Employee performance appraisal will be emphasized and refined to gain greater acceptance with the Laboratory's managers; succession planning and 360º feedback programs will be used more widely to develop more effective managers.

We continue to evaluate the effectiveness of our Affirmative Action Programs, their relevance in the marketplace, and their ability to address BNL's staffing needs. Our diversity program's goals focus on increasing the representation of women and minorities in the managerial and professional ranks. BNL continues to promote the hiring of women and underrepresented minorities as postdoctoral Research Associates and Scientific Staff. Working with Human Resources, the Diversity Office will strengthen recruitment and outreach to Historically Black and Hispanic Colleges and Institutions. Brookhaven values its diverse employee population and the richness of their cultural and ethnic backgrounds, and our Diversity Office partners with employees to provide programs and celebrations that recognize these heritages.

7.2 Information Technology Management

The Information Technology (IT) program supports the scientific research and business processes of the Laboratory by directing IT resources to realize the Laboratory's mission and goals. The Information Technology Leadership Council serves as an executive body for major IT issues and developed an IT Strategic Plan driven by the goals and objectives of the scientific programs and support operations.

The major strategic objectives for Information Technology are the following:

- Support Advanced Computation Research and provide an effective scientific computing infrastructure.
- Enhance network capabilities to meet the growing needs of the research program.
- Provide effective computer and network security.
- Implement a communications infrastructure and standardization program.
- Improve the usability and applications integration of PeopleSoft and related business tools.
- Implement a comprehensive Knowledge Management program.
- Sustain a program of IT training and professional development for IT staff and the user community.
- Implement an Information Technology benchmarking and metrics program.

BNL is revitalizing scientific computing support. One goal is to sustain and enrich the major computational centers of the Laboratory, the Center for Data Intensive Computing, the RHIC Computing Facility, and the BNL RIKEN Quantum Chromodynamics (on a digital) Signal Processor (QCDSP) and Quantum Chromodynamics On (a) Chip (QCDOC) facilities. At the same time, we are broadening the client base of the general-purpose Brookhaven Computing Facility, by better understanding the scientific objectives of the user community and providing more relevant and attractive systems and services. This will include enhancing the Linux Cluster, Silicon Graphics Onyx, and Sun Solaris platforms, and introducing modern software products such as Java, XML, and the Globus grid suite. In the well-established Visualization program, our emphasis is on providing hyper-resolution facilities and extending high quality visualization capabilities to the researchers' desktops. These improvements will be in evidence in FY 2002, and will continue incrementally thereafter.

Local and wide-area network capabilities are perhaps the most strategic asset. Effective and secure networking is vital to the highly collaborative research environment of the Laboratory's major programs and infuses every area of the Laboratory's business. For 2002, wide area network bandwidth must increase from 200 to 600 Mb/sec, and within five years, to 2500 Mb/sec to meet the estimated needs of the BNL research program, led by the requirements of RHIC and ATLAS. The local area backbones must increase commensurately, extending a high quality gigabit network to most areas of the site, and providing three to five times that bandwidth over the projection period.

A Communications Infrastructure and Standardization Program ensures maximum interoperability among applications meant to exchange information or work together, and optimizes efficiency in operations and maintenance. Expanded use of software licenses will encourage the use of common software tools and reduce software costs. An Enterprise Management System will be fully operational in FY 2002.

The Cyber Security initiative is particularly important to the Laboratory. BNL is implementing the BNL Unclassified Cyber Security Program Plan (CSPP) with the assistance of the Laboratory's Computer Security Advisory Council. In FY 2002, a complete Perimeter Defense Network, and host-based security and authentication services will be in place. However, the dynamic nature of cyber security demands a constant reassessment of BNL's security posture, including related tools and techniques, as the threats become more pervasive and sophisticated.

Our Business Information Management goal is to provide state-of-the-art computational resources that meet the business information needs of the research programs, including programming, administrative architecture, process engineering, security and applications architecture, application training, and archiving for major business systems. Recently, the Laboratory implemented several major new administrative information systems, starting with integrated financial management programs followed by human resource management programs, all purchased from PeopleSoft, Inc. All existing applications, except Labor Cost Distribution and Travel were moved from the legacy systems to a new Windows NT operating environment. In 2002, we started to replace the remaining legacy systems, thereby moving BNL to a totally integrated environment for financial and human resource support systems.

BNL is building a Laboratory-wide Knowledge Management System with commercial Web Content Management and Records Management Systems. The former enables us to index and archive information captured on our institutional web site and facilitates the application of consistent standards to the Laboratory's public web pages. The latter will provide web-based search and retrieval of Laboratory records and enhanced functionality for managing records. In the future, BNL will add a site-wide Enterprise Document Management System, which, when integrated with the Web Content and Records Management Systems, will provide cradle-to-grave information management as well as search capability across designated repositories. This will let users locate, re-use, and leverage the information resources to support BNL's research and business management objectives.

A Benchmarking and Metrics program was established to monitor efficiency, quality, and customer satisfaction. Key IT service categories and associated metrics were defined in FY 01, the baseline year. IT Metrics are being collected, reported, and published. A formal review process ensures a cycle of continuous improvement of the Benchmarking and Metrics Program. For FY 02, our emphasis is on refining the existing metrics.

Information Technology support is spread across the Laboratory's departments and divisions. General IT support is the responsibility of the Information Technology Division, the Business Systems Division, and the Information Services Division. Because this function is dispersed, IT's infrastructure will benefit significantly from the opportunities for consolidation and improvement envisioned in the BNL Site Master Plan and Strategic Building Plan.

7.3 Communications Management

BNL has been successful in promoting the value of our science programs to the general public. Physics research projects, such as RHIC and g-2, were featured prominently in the national and international media. A wide variety of other fields and disciplines, such as medical research on addiction, genomics, protein imaging, and air quality also have received increased attention in all media. At the same time, the Laboratory continues an ongoing dialogue with the community and a broad spectrum of stakeholders about legacy environmental issues and our commitment to protect the environment and minimize waste generation.

Our three- to five-year goal is to generate community enthusiasm for our research programs and new initiatives and to increase confidence and trust in our cleanup efforts. To achieve these goals the Laboratory will

- Continue to familiarize the community with the type and quality of our scientific research,
- Generate local pride in Brookhaven as a community asset, internationally renowned and contributing to the educational and economic benefit of Long Island,
- Involve stakeholders and the general public through tours, student visits and similar activities that make Brookhaven's science and Brookhaven people familiar, friendly, and accessible,
- Position Brookhaven as a preferred location to do science by making it attractive to both users and potential employees,
- Work with our DOE colleagues to foster multi-laboratory initiatives and promote the national laboratory system,
- Seek input from stakeholders on issues of importance to them.

BNL will vigorously pursue efforts to strengthen the foundation of trust and confidence it has built with the community. We will continue to enhance those community programs that have been useful and informative to the public, and effective and beneficial to the Laboratory. For example, the museum education and tour programs have brought more than 75,000 students and visitors to the Laboratory in the past three years. We will sustain this level of students and visitors and strive to enhance their positive experience.

The Laboratory also will continue to support programs that reach out to the community, including the Ambassador Program, Envoy Program, Exhibits, Speakers' Bureau, and the Stakeholder Relations Program, emphasizing the following messages.

- The Laboratory is a rare scientific resource – an asset to Long Island for its intellectual merit, its economic contributions, and its educational value.
- The Laboratory itself is a member and a stakeholder in the community. We participate in mutual aid, blood drives, the United Way, etc. We have an abiding commitment to Long Island because we live here, work here, and raise our families here.
- The Laboratory is dedicated to proactive pollution prevention, waste minimization, and the reduction or elimination of hazardous waste on site.
- The Laboratory acknowledges its environmental problems and is working diligently to correct them, in cooperation with stakeholders.

The Community Advisory Council (CAC) advises the Director on issues of importance to the community at large, and to the organizations represented on the CAC. The Laboratory supports an ongoing dialogue with the CAC on programs of interest, supplying data as requested, facilitation services, administrative support, and action-item coordination. The Laboratory will continue to nurture the CAC by supplying support services to the council and its subcommittees.

We will prominently feature developments in the exciting search for quark matter at the Relativistic Heavy Ion Collider (RHIC), addiction research, the Spallation Neutron Source collaboration, the ATLAS detector, and other advances in biotechnology, chemistry, and physics.

The World Wide Web is a critical vehicle for communicating the mission and achievements of the Laboratory to all stakeholders, internal and external, local and international. Information on the Laboratory's web site will be timely, accurate, interesting, and useful. Stakeholders will see www.bnl.gov as a primary source of reliable information about the Laboratory.

7.4 Environment, Safety, Health and Quality Management (ESH&Q)

Activities related to protecting the environment, the safety and health of workers and others, and the quality with which all work is done, are integrated into work from the planning stages to completion. ESH&Q activities are integrated into work by tools that assist employees in applying the Five Core Functions of Integrated Safety Management (ISM), starting with the initial plans for the work. Managers responsible for the work are expected to understand the hazards, establish appropriate controls before work is authorized to start, and ensure appropriate control of all workplace risks.

BNL successfully implemented Integrated Safety Management (ISM), achieved ISO 14001 registration, and improved radiological controls, chemical safety, pollution prevention, line ownership, and the staff's awareness of ESH&Q responsibilities. While the Laboratory has improved its reputation, continued success is imperative. New Laboratory science and technology initiatives, such as RHIC II/eRHIC, Super Neutrino Beam and Nanoscience, as well as site infrastructure revitalization and environmental restoration work, will require continuous involvement of ESH&Q disciplines to maintain work planning and control processes consistent with our commitment to safe workplaces and environmental stewardship.

Our goal is to achieve and sustain operational excellence, i.e., operations that are safe, environmentally responsible, and cost-effective. As part of our strategy, we will make every effort to reduce indirect costs by eliminating redundancy and non-value added work. New approaches to achieving efficient support that we will consider include

- shared resources between support units,
- purchased services from the Laboratory's support organizations (e.g., Waste Management, QA, Management Services, Information Technology, Facility & Operations),
- purchased services from outside the Laboratory.
- enhanced resource sharing and integration with corporate partner /sister laboratories.

Our objective is to reprogram savings into investments in our core capabilities, and to support business development, while maintaining charge-out competitive rates.

7.4.1 Environmental Management

BNL continues to reduce, eliminate, and prevent environmental impacts from its operations and to restore the environmental quality of the site. The key elements of our approach include protection, pollution prevention, and environmental cleanup.

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BNL minimizes environmental impacts through implementing our ISO 14001 certified Environmental Management System (EMS) for all facilities and operations. The Laboratory stresses continuous improvement to lessen or eliminate the environmental impact over time, and will continue to seek reductions in its operational discharges and potential impacts to the environment.

A second component of the Environmental Management System is our multi-media environmental monitoring program. This integrated activity ensures coordination among the program's customers and strengthens the capabilities and comprehensiveness of the Laboratory's environmental monitoring program.

Our waste minimization and pollution prevention programs are strategically important by avoiding creating waste and producing excess materials that might become waste. The approach is to plan for waste avoidance at the earliest stages of planning an experiment, continually looking for opportunities to drive down the cost of managing wastes, and minimizing waste-related risks to the environment.

Concurrent with the pollution prevention activities, our waste management program's goals are to minimize waste generation, to use recycling and reduction options in lieu of treatment and disposal, and to manage wastes off-site to prevent stockpiling. With the transition of the Waste Management function from the DOE's Office of Environmental Management to the Office of Science (SC), Laboratory organizations that generate waste are given a history-based "allotment" of the waste management budget from SC. In FY03, however, waste management costs must be fully recovered from the waste-generating organizations. A new allocation system is being developed to fully recover the costs of needed work, provide for program continuity, and minimize costs.

BNL is committed to accelerating the completion of its environmental restoration mission. The Laboratory's restoration program is fully engaged in several substantial cleanup projects involving contaminated soils, groundwater, the river environment within and adjacent to the BNL property, and facility decommissioning. We intend to accelerate our efforts by using sound project management practices, value engineering, and innovative contracting strategies.

The Laboratory continues to make significant progress in Environmental Management. Several notable accomplishments include the following:

- Maintaining Lab-wide ISO 14001 registration, officially obtained on July 10, 2001, with an annual surveillance audit in June 2002.
- Completing annual environmental reviews and updates of 130 industrial processes and 1870 experiments, identifying all wastes, emissions and effluents, regulatory requirements, and pollution prevention opportunities. These processes originally were reviewed and documented in the Process Assessment Project.
- Continuing to execute meaningful pollution prevention projects, which have resulted in substantial cost savings and have reduced radioactive and hazardous waste generation and disposal. Continuing work to close out the Facility Review Disposition Project. This project identified legacy issues identified from a review of the entire operating history of the site and an assessment of all Laboratory systems, facilities and operations. The higher priority issues were dispositioned, and the focus is now on completing the project.
- Processed and disposed of a majority of wastes at the former Hazardous Waste Management Facility.
- Expanded groundwater monitoring and integrated environmental restoration and environmental surveillance monitoring, while continuing to systematically streamline the groundwater monitoring to reduce costs.

- Completed several important environmental restoration activities including,
  - Achieved Final Records of Decision for the cleanup of groundwater and soil contamination at BNL and for Operable Unit VI.
  - Excavated and disposed of radiologically contaminated landscaping soil.
  - Drafted Proposed Remedial Action Plan and Record of Decision for Operable Unit V, Peconic River Clean-up, and finalized the Record of Decision for the Sewage Treatment Plant.
  - Constructed and commissioned seven treatment systems for removing contamination in groundwater; treated more than a billion gallons of groundwater to date.
  - Installed an additional groundwater treatment system to control the source of the tritium plume at the High Flux Beam Reactor.
  - Completed baseline planning for the BGRR Decommissioning Project and three key removal actions leading to the decommissioning and partial dismantlement of the former Graphite Research Reactor complex.

In FY 03 and beyond, the Laboratory will focus on the following:

- Improving the Environmental Management System.
- Completing the development of the Environmental Information Management System to allow all stakeholders Internet access to the monitoring data.
- Improving operational and engineering controls to improve the groundwater protection program, emphasizing the prevention of any further insults to groundwater quality.
- Ensuring that wastes from current Laboratory activities are managed properly to ensure regulatory compliance and cost efficiency.
- Focusing on reducing the total project costs for the Environmental Restoration Program and achieving or accelerating milestones for remediation.
- Planning for, and preparing to, implement Long-term Stewardship of remedial actions.

7.4.2 Safety and Health

BNL will continue to improve the radiation exposure-monitoring database, chemical exposure database, process reviews, experimental safety reviews, Risk Trac, Workers Compensation database, Injury/Illness database, and Lost Workday Case Rate Reporting.

The completion of the Integrated Safety Management (ISM) verification set the stage for the maturing of many ESH initiatives. Continuous emphasis on the ISM core functions and guiding principles will help the Laboratory prioritize its efforts to capture work planning and controls as the fundamental building block of BNL's ESH&Q program. We continue to improve the clarity with which we define each worker's Roles and Responsibilities Accountabilities and Authorities (R2A2) and the overall depth and effectiveness of our self-assessments. We will increase the field presence of safety and health professionals by supplementing the existing field staff with backup from other members of the Safety Evaluation Group. Adding a certified industrial hygienist whose primary duties include field support, and work planning and control assistance, resulted in positive feedback from line organizations.

7.4.3 Quality Management

The Laboratory's Quality Management Program meets the requirements of the DOE’s O 414.1A and 10CFR830.120. Quality requirements are incorporated directly into Management Systems and subject areas. This approach assures incorporation of quality activities in the everyday operations of the Laboratory, and reinforces the understanding that quality is each employee's responsibility.

In FY01 and FY02, the Quality Management Program was assessed using a Malcolm Baldrige-Based methodology. This approach evaluates the “maturity” of laboratory management processes that are used to satisfy QA program requirements in three areas; Approach/Definition, Deployment/Implementation, and Assessment/Improvement processes. The process was reviewed and endorsed throughout the DOE complex, and is being adopted by another laboratory. The assessment determined that all QA program requirements are being satisfied at the Laboratory. However, the maturity of the key processes for the QA program varies. Based on the results, management systems stewards prioritize issues and take appropriate actions for improvement.

Beginning in FY02, the DOE and the Laboratory’s senior management agreed to substantially increase the weighting for the evaluation rating of the Laboratory’s self assessment and improvement program in the Critical Outcomes. This agreement is forward thinking, aligned with Undersecretary Card’s streamlining agenda, and helps address several issues related to performance-based management contracts in a DOE laboratory construct. However, the ability to objectively measure the adequacy and effectiveness of a self-assessment and improvement program presents many challenges. A Baldrige-Based methodology, similar to the process described above, is being piloted/utilized for this purpose.

7.5 Safeguards and Security Management

The Safeguards and Security organization supports the basic scientific mission of DOE and the Laboratory by

- protecting DOE's Special Nuclear Materials, Classified Matter, and Property against theft, diversion, or destruction,
- preventing the loss of information or sabotage of programs that could have significant financial impact,
- preventing radiological or toxicological sabotage that would endanger employees, the public, or the environment.

Laboratory-wide programs, such as Operations Security, Technical Surveillance Countermeasures, Classified Computer Security, Communications Security, Counterintelligence, Foreign Visits and Assignments, Material Control & Accountability, Property Protection and On-Site Hazardous Materials Packaging, and Transportation Safety, aid in reaching these objectives. We also implement preventive programs, such as property-protection access controls, site surveillance, community crime prevention, and Security Education and Awareness.

Safeguards and Security staff establish guidelines, plans, and strategies to protect sensitive or classified information, export information, Cooperative Research and Development Agreements, protocol visits, and Work for Others.

The BNL Senior Counterintelligence Officer (SCIO) works closely with BNL's Safeguards and Security personnel and the Operations Security (OPSEC) Working Group, as well as other Federal agencies. The CI program includes the protection of information, foreign travel briefings and debriefings, host debriefings, and interactions with the foreign visits and assignments office. The SCIO leads the

Laboratory's efforts to maintain an up-to-date list of sensitive technologies.

The Safeguards and Security Enhancements Plan is a long-range plan to ensure that security is continuously improved in an efficient and cost-effective manner. Subject-matter experts annually review the Plan to ensure that the necessary protective measures are planned systematically to identify and prioritize vulnerabilities. BNL also is pursuing an action plan for implementing DOE's Integrated Safeguards and Security Management (ISSM) policy.

The continuing security need for, and importance of, a Visitor Reception Center was heightened after the World Trade Center bombings. BNL has no facility for visitors, vendors, or contractors to obtain necessary information about programs, regulations, restrictions, or to fulfill training requirements before entering the site. This facility would provide contractor indoctrination and safety training; employee orientation training including security education, a training film library, the housing office, badging and vehicle registration services, a public relations information area, a public reading room, Human Resources information (e.g., job postings), and parking and vehicle inspection areas. All these functions would take place without entering the BNL site, resulting in better access control, better informed and trained employees, guests, and contractors, and enhanced community relations.

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8.0 Site, Facilities and Infrastructure Management

8.1 Description of Laboratory Site and Facilities

BNL's site is approximately 5,320 acres, 30% of which is developed. There are 378 buildings (24 currently excess) and 294 portable structures (Table 5). Portable structures are facilities not meeting the criteria for real property buildings that house people, equipment, or are used for storage. These structures include trailers, sheds, containers, railroad cars, and HAZMAT storage units, etc. Many buildings date back to World War II, some earlier. Most major permanent buildings, excluding those constructed for RHIC, were built in the 1960s (Figure 11).

Table 5 - Laboratory Space Distribution and Replacement Plant Value

LABORATORY SPACE DISTRIBUTION

Facility Type	Area (Sq. Ft.)
Active Buildings	3,958,657
Excess Buildings*	244,309
Portable Structures	94,990
Leased Off-site	1,000
TOTAL	4,298,956

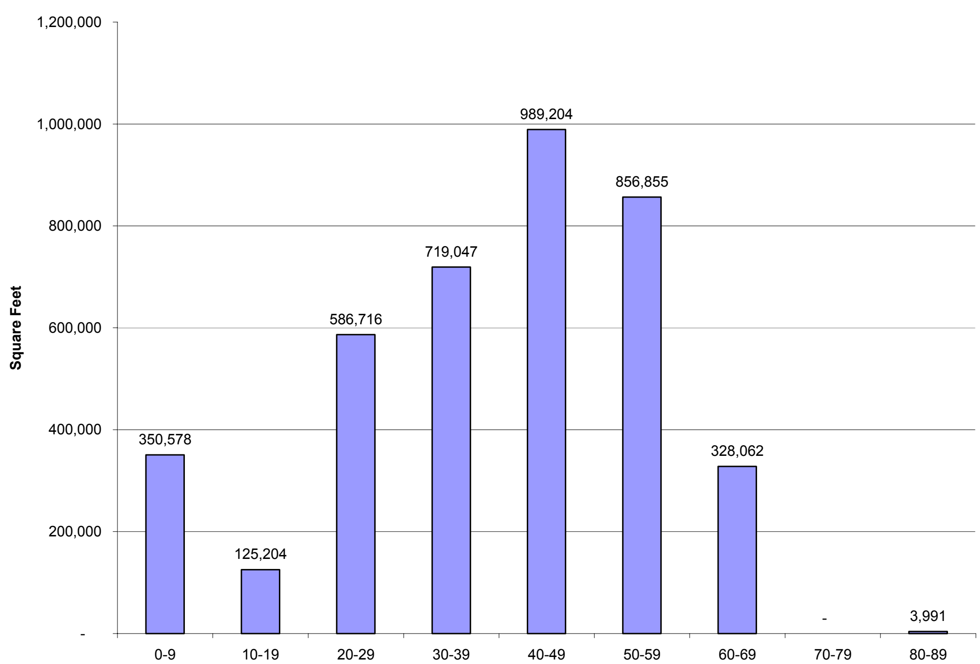
Source: DOE FIMS Database 09/30/02
* Scheduled for demolition FY02 = 54,049 SF

REPLACEMENT PLANT VALUE

Facility Type	Current $
Active Buildings	1,384,256,889
Surplus Buildings	79,979,290
Active OSF*	1,188,761,930
Excess OSF	64,554,250
TOTAL*	2,717,552,359

Source: DOE FIMS Database 09/30/02
*Significant increase due to TFA of RHIC

Figure 11 - Age Distribution of Active Buildings in Years (Excludes Excess Space)
(Average Age, Weighted by Square Footage = 40.3)



BNL is served by site-wide utilities that include electrical-, steam-, sanitary sewer-, storm sewer-, and potable-water systems. In addition, there are limited distribution systems for chilled-water and compressed air. Figures 12 and 13 illustrate the condition and use of existing Laboratory space.

Figure 12 - Use & Condition of Non-Surplus Space – Using FIMS Data dated 9/30/02

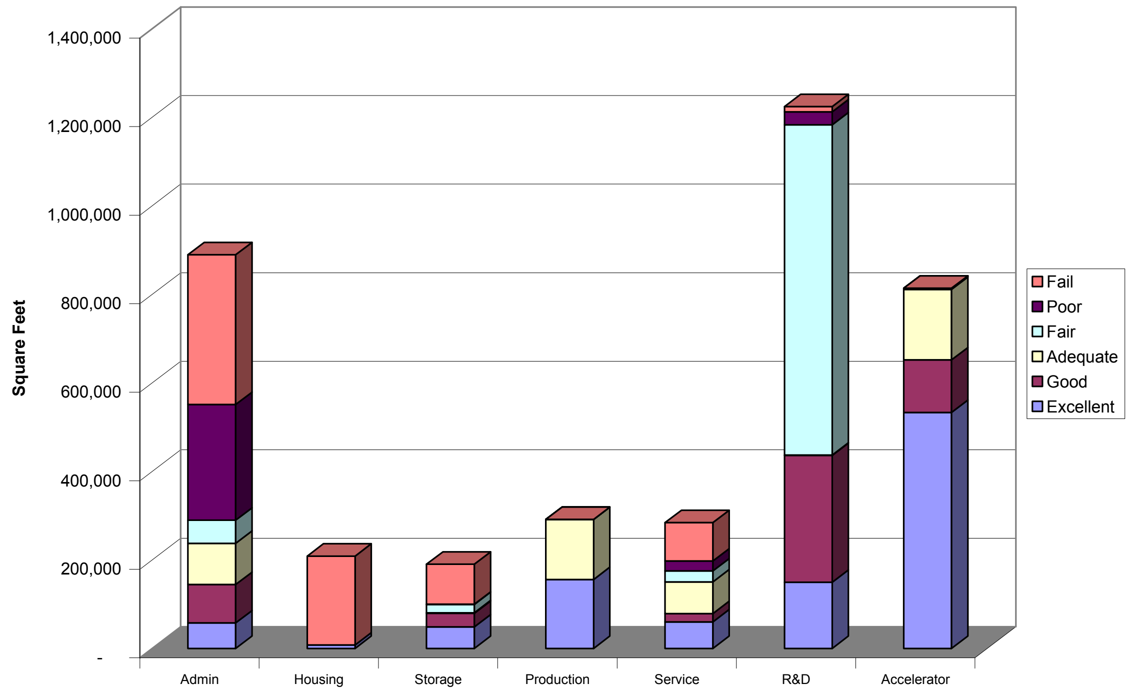
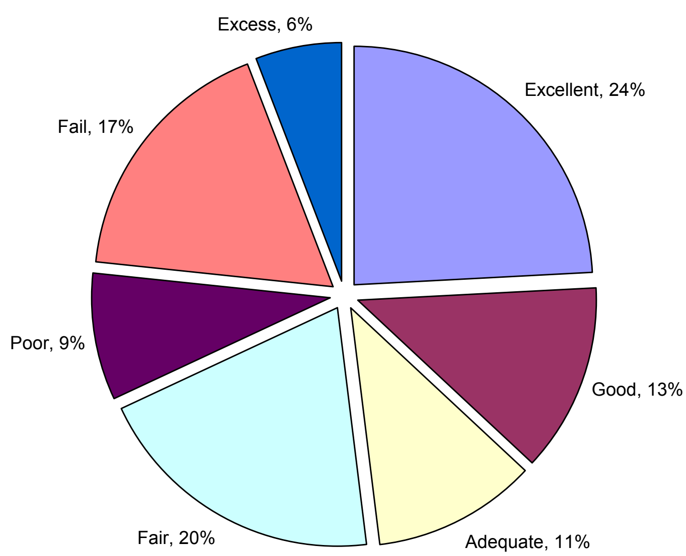


Figure 13 - Condition of Laboratory Space – Based on FIMS Data dated 9/30/02



8.2 Trends

Buildings and Space Utilization (Table 6): Since we anticipate that, for the most part, new construction will only replace existing buildings or meet specific scientific needs, the amount of space and buildings should not change significantly. The new Excess Facilities Demolition Project will help to rid the site of buildings no longer needed. There is no clear definition of trailers; BNL tracks all portable structures used to house people and equipment, or used for storage. All portable structures are included in the space-charge program. There has been more than a 10% decline in the numbered portable structures over the past five years. Since 1996, BNL has had one existing lease for a 1000 sq. ft. apartment for staff involved in a program in North Carolina.

Table 6 – Buildings and Space Utilization	**FY98**	**FY99**	**FY00**	**FY01**	**FY02**
Building Area (SF x 1,000,000)	4.2	4.2	4.2	4.2	4.2
Buildings Added	9	5	0	2	3
Buildings Removed	0	9	0	1	14 [1]
Portable Structures	317	379 [2]	383	381	314 [3]
Storage Space (SF x 1,000)	523	549	540	541	546

1. Includes buildings scheduled for demolition in FY02
2. Increased due to major effort to identify portable structures not previously inventoried
3. Decreased due to major effort to rid the site of portable structures in poor condition prompted by space charge and a program where the Laboratory G&A paid for the disposal, saving individual departments the expense.

Surplus Facilities (Table 7): The decrease in the Laboratory's population has allowed consolidation out of buildings where repair is no longer cost-effective. This has increased the number of surplus buildings, most of which are non-contaminated. Surplus contaminated buildings under the Office of Science have increased to 3, as these facilities have not yet been accepted by the DOE-EM; they include Building 491, the Brookhaven Medical Research Reactor, which is expected to transfer to EM. The remaining two are 650 and 650A, both of which were formerly used as part of our waste management operations.

Table 7 – Surplus Facilities	**FY98**	**FY99**	**FY00**	**FY01**	**FY02**
Contaminated Surplus Facilities – SC	1	1	2	2	3
Contaminated Surplus Facilities – EM	8	8	13	13	13
Non-contaminated Surplus Facilities - SC	12	14	6	14	18 [1]

1. Buildings scheduled for demolition in FY02 were not deducted from this number.

Maintenance (Table 8): Deferred maintenance has continued to rise as a result of the following efforts:

- Increased CAS inspections
- Site Master Plan Study which identified significant needs in all our major laboratory/office buildings
- Engineering analysis applied to old buildings where significant inspections are not cost effective because the buildings are not worth the expense required to ensure their long-term preservation

While the indirect funded site maintenance budget has increased, a study performed this year indicated that the funding level for routine maintenance is only 59% of what it should be, and our capital renewal (replacement of building systems no longer economically serviceable) is even worse, at 39% of required levels.

Table 8 – Maintenance	FY97	FY98	FY99	FY00	FY01
Deferred Maintenance ($ x 1,000,000)	N/A	51	106	140	341
Site Maintenance – Indirect ($ x 1,000,000)	6.8	9.7	11.9	12.0	14.4

BNL, the DOE-BAO, and the DOE-CH are working with the DOE-SC 82 to clarify the definition and calculation issues related to deferred maintenance. We provided comments and recommendations to Dr. R. Orbach's proposed guidance on maintenance expenditure. BNL is evaluating the potential impacts if the draft guidance is implemented. We will continue to work with the DOE-SC 82 to monitor and reduce the deferred maintenance at BNL.

8.3 Assets Management

The Laboratory maintains a comprehensive and cost-effective Assets Management Program efficiently encompassing our use, control, and disposal of assets.

Real Property: Real property records are maintained in the DOE's FIMS and reconciled with the Laboratory's financial records. The accuracy of the FIMS records and building key plans are reviewed during field surveys of the Facility Inspection Program. Information on the buildings' conditions, deficiency lists, and requests for upgrades also are reviewed to assess each facility's life cycle and to identify those assets for which further capital investment is warranted, or for which demolition is preferable. The Laboratory uses either the DOE's Office of Science landlord funds (through G&A) or the DOE's Environmental Management funds (direct funding) for demolishing buildings.

Personal Property: BNL undertakes an active "Walk-Through" Program to ensure that all appropriate equipment is identified and properly controlled, and to monitor and identify any idle or surplus materials. The Laboratory also has a site inspection program to monitor the accumulation of materials. These programs, coupled with the Waste Minimization Program, allow the Laboratory to quickly and efficiently dispose of surplus assets, consistent with the appropriate Federal and DOE Property Management Regulations.

Space Management: In FY 98, BNL began a charge-back program that charges departments and divisions for their use of space, based on the BOMA Area Measurement Standard (ANZI Z65). It includes all buildings and portable structures. The rates for occupied spaces are adjusted each quarter. Each space is classified and assigned rates and categories as shown in Table 9.

Charging for space has a benefit in terms of encouraging consolidation. This was particularly true for those groups that have reorganized and who carefully considered the use of space in planning their revised organizations.

8.4 Detailed General Purpose Facilities Plans and Resource Requirements.

BNL will continue to use the funds available through the SLI Program, to upgrade environment, safety, and health (ES&H) protection, improve utility systems, increase efficiency through consolidation, and replace, mothball, or demolish aged inefficient facilities. The anticipated SLI line-item requirements outlined in the Strategic Facilities Plan from FY 02 to FY 06 are approximately $144 million. Based on a ten-year average funding level of $5.5 million, a $116 million shortfall is expected by 2006.

Table 9 - Space Charge Rates and Categories

SPACE TYPE	DESCRIPTION	FY01 RATE, $	FY02 RATE, $
0	Common Space (corridors, bathrooms, electrical- and mechanical- space associated with operations of the facility.)	0.00	0.00
1	Normally unoccupied space, such as programmatic equipment support spaces, electrical- and mechanical-space associated with the operation of the program, and storage spaces	3.85	4.05
2	Normally occupied space, including industrial space, such as machine shops, technical- and craft- shop areas; non-laboratory high-bay industrial areas, such as manufacturing, testing and assembly areas; and, commercial-type space, such as the Research Library	10.15	10.70
3	Normally occupied space, such as offices, laboratories, conference rooms, and department/division libraries.	14.90	15.70
4	Normally inaccessible spaces occupied by large research machines, including associated tunnels, caves, etc. All maintenance is charged back to the occupant.	0.00*	0.00*
5	Housing. All maintenance is charged back to the Administrative Services Division.	0.00*	0.00*

- Maintenance is charged-back based on actual costs.

Inadequate funding for the General Purpose Facilities program is extending the cycle of high operating and maintenance costs, rather than securing prudent reductions through increased investment in new facilities. The Laboratory is concerned about the inability of the SLI Program to address ES&H needs while dealing with infrastructure needs.

Within the planning period, BNL proposes new programmatic facilities, including a User Research Center ($15.4 M) and a Center for Functional Nanomaterials ($82 M). In addition, there are several proposed SLI projects for new buildings, including an Energy Sciences Center ($18.4 M) to consolidate related programs into new modern flexible-use laboratory/office space, and a multi-phased Research Support Center (four phases at $18.2 M each) to improve operational efficiency by consolidating support functions so allowing the demolition of 60-year- old inefficient wood buildings. In addition, the Research Support Center will reduce backlogs in areas such as Life Safety compliance, roofing, duct cleaning, and replacing mechanical equipment. A multi-phased Support Shops Complex (Phase I $5.5 M) will combine the functions of Plant Engineering and Central Shops into one area of the site, improving their overall operational efficiency and allowing the demolition of 60-year-old, inefficient wood buildings.

During the same planning period, BNL also proposed a series of projects to renovate its major laboratory/office buildings that, on average, are over 35 years old (Phase I $29.3 M, Phase II $14.3 M, and Phase III $25.3 M). While the buildings' shells and superstructures are sound and will last for another 50+ years, the interiors and mechanical systems have reached their end life and badly need replacing.

BNL's utility systems are fairly reliable; however, to maintain this reliability, additional projects are proposed to replace aged components of the potable water and steam distribution systems ($8 M each). Furthermore, the Central Chilled Water Facility needs an additional ($9 M) to support planned facilities and restore firm capacity. To meet the requirements of the Clean Air Act, Halon firesuppression systems must be phased out ($5 M). Other utility concerns that will become future priorities include

- The condition and longevity of the Site Fire Alarm System that is rapidly becoming obsolete. (To address this issue, a new planning team was formed to develop a long-term strategy with associated projects and costs.)
- The need to expand BNL's high-speed network backbone to include site-wide plant systems including fire alarm, energy management, and plant control systems.
- The need to upgrade electrical power quality and associated monitoring to ensure compliance with utility requirements.

While the trends indicate that maintenance funding has increased, this is somewhat misleading as the base year was during a period of extremely low maintenance budgets in which funds were redirected to address higher priority ES&H needs. In addition, during this same time, several facilities related to RHIC became operational, so increasing maintenance needs. The current deferred maintenance, comprised mostly of major maintenance projects, is more than 20 times the annual funding for those types of projects. Furthermore, with increased facility inspections, the backlog is growing. A significant portion of the maintenance backlog would vanish if the capital renewal projects proposed in the Site Master Plan were constructed. Then, the remaining backlog would be quite manageable, without increasing maintenance funding levels significantly.

8.5 BNL Sustainable Design Implementation

BNL has implemented Sustainable Design principles in its construction, operation, and maintenance activities since 1998 and will aggressively implement sustainable design in any new building projects. A full-time environmental engineer, working in concert with BNL's longstanding Energy Management Group, is dedicated to reviewing BNL Plant Engineering's construction, operation and maintenance activities to ensure they incorporate pollution prevention practices, maximize the use of recycled materials, and adopt energy efficient practices, wherever feasible.

BNL has actively strengthened the technical capability of its engineering and design staff in sustainable design. Our engineering staff members are involved in the EPA/DOE's Labs for the 21st Century Initiative and are frequent attendees at Sustainable Design, Labs 21 and Leadership in Energy and Environmental Design (LEEDS) training seminars.

BNL's design procedures require a project ESH review before starting detailed design to assure that ESH requirements, including opportunities for pollution prevention and sustainable design, are identified and incorporated as early as possible in the project. Requirements for final design review assure again that these features were incorporated in the design before bidding and construction. Any new building projects will incorporate LEEDS criteria with the goal of achieving the maximum LEEDS rating for the building appropriate for its use and budget.

8.6 Strategic Facility Plan

The bulk of the Laboratory's science buildings were constructed in the 1950s and 1960s. They are of permanent construction and remain structurally sound, but are at an age where major rehabilitation of the electrical and mechanical systems and interior finishes is needed to ensure reliable continued support for the programmatic mission and our ability to attract top researchers. BNL's Strategic Plan proposes rehabilitation projects that will achieve these results.

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Progress toward consolidating staff into permanent buildings and demolishing sixty-year-old wood buildings has been on-going for the past five years and is expected to accelerate with the construction of the Research Support Building, scheduled for a FY03 start. This project will eliminate more than 50,000 square feet of those buildings.

EENS is the last remaining science directorate still operating in WWII wood buildings. The FY04 proposed Energy Sciences Building will consolidate these key mission functions that are expected to contribute to the Laboratory's growth in the next 5 to 10 years. The new facility will expand their mission capabilities and allow further demolition of antiquated space.

The other mission group still using WWII buildings is the user groups associated with RHIC and the NSLS. The proposed User Research Building will consolidate them into new facilities adjoining the Physics Building located across from the National Synchrotron Light Source. Once again, wood buildings will be vacated and demolished.

Additional reduction of sixty-year-old space is sought through proposed third-party-funded projects. BNL is aggressively exploring this option with potential third parties and will present specific proposals to the DOE in the near future.

The Excess Facilities Disposal Project was begun this year and will demolish more than 100,000 square feet of antiquated buildings over the next several years. Some departments are dispersed over many locations on site and the demand for user space is increasing. Line-item projects proposed for the next several years would address these issues.

In general, the utility systems are sound and projects to improve the system's reliability were completed recently or soon will be complete. In addition, several new projects are proposed in the plan, including replacing the aged components of the potable water and steam distribution systems, expanding the Chilled Water Facility, and expanding and improving the reliability of the networking system.

Deferred maintenance backlogs have increased over the years due to additional facility inspections by outside A/E firms, and identification of additional maintenance needs through the Master Plan process. Non-programmatic maintenance expenditures for buildings are approximately 1.4% of Replacement Plant Value (RPV). These percentages will vary depending on maintenance charged-back to programs and other operating accounts. Without an aggressive capital renewal campaign, funding for maintenance and repair projects will need to increase significantly to prevent many infrastructure deficiencies from becoming environmental, safety, or health issues, and/or causing further damage to the infrastructure assets. These expenditures will steadily consume a larger share of the science dollars.

The current backlog of General Plant Projects (GPP) is \$53M. Over the past years, BNL averaged appropriations of ~\$11M/year in combined GPP and Science Laboratory Infrastructure (SLI, former MEL/FS program). With a GPP budget that has averaged slightly over \$6.0M annually, it has been extremely difficult to tackle larger building projects since a single project would have consumed up to 90% of a fiscal year's GPP budget. This backlog is expected to increase at a faster pace as existing facilities continue to age. The Strategic Facilities Plan proposes an increase to allow the funding of one major GPP project over the current funding level.

Line item construction for new program-support facilities and general-site facilities has not kept apace with the program needs or the needs of the site. The bulk of capital funds required to meet the infrastructure objectives of the Laboratory would need to be provided through line item construction projects and third party financing. There are several categories of projects:

- New buildings that are DOE funded,
- New buildings that have potential for 3rd party financing,

- Major renovations of permanent science buildings, and
- Utility improvements.

These projects total over $600M with approximately $80M in programmatic needs, $85M in third party financed construction (e.g., short- and long-term housing), and the balance, $435M, in SLI funding needs.

8.6.1 Planning Assumptions

Many factors influenced the Strategic Facilities Plan. Among these are the following:

- Programmatic growth, if achieved, will provide additional funds to address infrastructure backlogs, created due to past budget constraints.
- Third-party funded facilities will further reduce infrastructure backlogs.
- The lack of available space necessitates the continued use of wood-frame buildings that are over 50 years old and forces the dispersal of departments over several buildings, resulting in decreased operational efficiency.
- User space is inadequate, and user needs will continue to increase.
- The Laboratory's information infrastructure needs significant upgrades.
- Roofing systems are failing or have failed and need replacing.
- Peak electrical demands will increase with full operation of RHIC.

In developing the Strategic Facility Plan (SFP), these and other factors served as the planning base, including assumptions about the future of the science programs at BNL, the general and administrative services that need to offer more efficient support, the nature of the site and utilities, and the quality of life for both users and staff.

If we are to establish quality workspaces for our employees and users, we must replace over 1,000,000 square feet of the pre-1960 wood and masonry buildings. In addition, we must provide modern laboratory and office space that has the flexibility to adapt to changing program needs and is supportive of multidiscipline teams. Modern office and other workspaces also must be available for non-scientific organizations to ensure efficient operations that effectively support the scientific mission.

To create a coherent user experience, we must make changes that facilitate navigation and access around the site, group support services together to make user access and interactions with these services easier, and provide modern, efficient workspaces and attractive, comfortable, and affordable living accommodations.

If we are to keep our business practices efficient and provide reliable scientific facilities to obtain, process, and analyze data, we must embrace the latest changes in information technology. This includes ensuring that the latest advances in high-speed networking and cyber-security are deployed and seamlessly integrated into our scientific and business practices.

Finally, to establish a feeling of openness with our surrounding community, we must be cognizant of their concerns and provide facilities that encourage them to visit the Laboratory, to learn about our science and technology, as well as the history and heritage of the site. We also must provide support facilities that ensure their entire experience on site is a positive one.

Implementing the Strategic Facilities Plan will transform BNL's infrastructure into an exciting, world-class platform able to support the full range of 21st century science and technology. With many projects offering an attractive return on investment, operating costs will be lowered and maintenance needs matched to capabilities. Excellence in our environmental, safety and health, and operational performance will be assured. Most importantly, the new and renovated facilities will create an aesthetically impressive, intellectually stimulating environment that will leverage the DOE's investment in major user facilities to produce unprecedented levels of outstanding scientific output for the balance of the 21ST century and beyond.

8.6.2 Plan for Modernization

The Strategic Facility Plan, revised in 2002, and the companion Site Master Plan 2000 provide a roadmap for creating a flexible site framework for growth and renewal. The fundamental elements of the plan include the following:

- Replace obsolete, inefficient wood-frame buildings, and renovate permanent facilities.
- Construct new facilities that are "Green Buildings," designed to be environmentally friendly and energy efficient, meet current health and safety requirements, and meet Americans with Disabilities Act (ADA) requirements.
- Reorganize the BNL campus into functional and efficient zones for research, support services, and residential functions.
- Stimulate intercommunication and a sense of community among BNL scientists by concentrating daily activities into a central area easily accessible by pedestrians.

This roadmap would consolidate the current diffused facilities by concentrating function and constructing in the already developed central areas. The plan establishes a flexible framework for renewing the site over 10-20 years, and well into the foreseeable future. The site would consist of a "Main Street" with adequate parking located adjacent to primary buildings; traffic and pedestrian flow patterns would be redirected, and housing reorganized to provide long-term accommodations remote from the central campus, medium-term housing adjacent to central functions, and short-term transient housing with immediate access to research activities. The resource chart in the Strategic Facility Plan represents one means of funding the Plan (see Table10 and Figure 14) over the next 10 years.

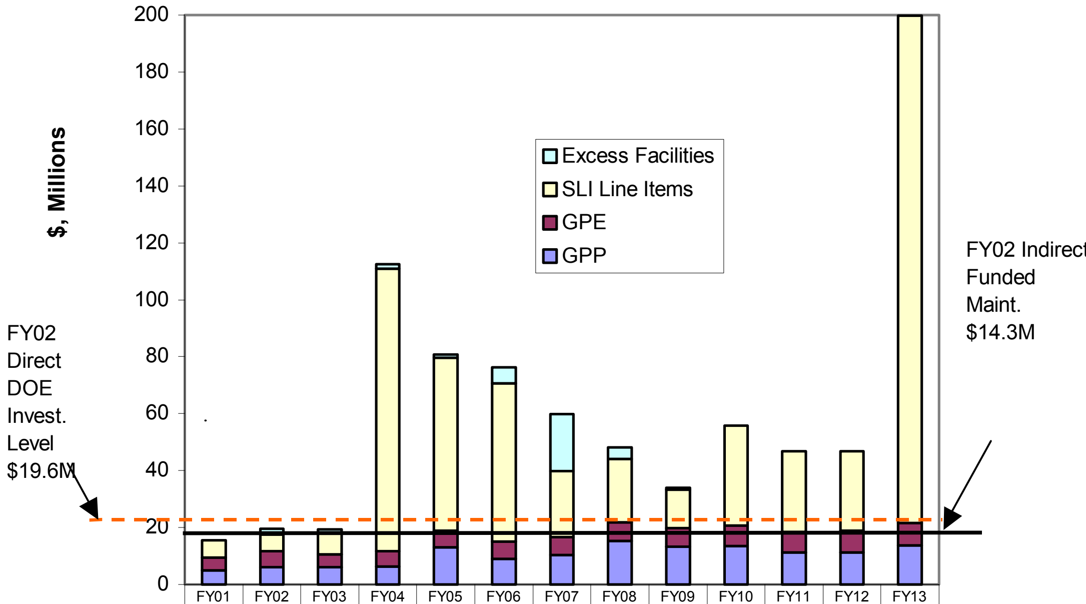
Table 10 - Strategic Facilities Plan – Funding Needs Table

	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13
DOE Investment	15.5	19.6	19.3	112.5	80.7	76.2	59.9	48.2	33.9	55.9	46.7	46.7	199.7
Maintenance-Indirect	12.0	14.3	14.8	15.3	15.9	16.4	17.0	17.6	18.2	18.8	19.5	20.2	20.9

The plan proposes improvements that increase the productivity of our users while at BNL, thus increasing the scientific output from DOE's investment in our major facilities. New facilities would consolidate RHIC users and BNL scientific staff participating in RHIC science into modern space, including offices, conference rooms, and administrative support and seminar space. Existing permanent laboratory/office space would be renovated and made available for NSLS users. The user support areas at the NSLS would be expanded. The network infrastructure serving users' workspaces would be improved.

Science in the future will be more interdisciplinary, and existing buildings will need to be reconfigured and supplemented with new flexible laboratory buildings that can accommodate multidisciplinary teams. The plan proposes renovating facilities whose projected lifetime is well beyond 20 years, but whose systems (mechanical, electrical, etc.) have reached the end of their service life.

Figure 14 - Strategic Facilities Plan – Funding Needs Table



	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13
Excess Facilities	0.0	2.0	1.0	1.5	1.0	5.5	20.0	4.0	0.5	0.0	0.0	0.0	0.0
SLI Line Items	6.0	6.0	7.7	99.2	60.9	55.6	23.2	22.3	13.5	35.3	28.2	27.9	178.2
GPE	4.5	5.5	4.5	5.4	5.8	6.0	6.3	6.5	6.7	7.0	7.3	7.5	7.8
GPP	5.0	6.1	6.1	6.4	13.0	9.1	10.4	15.4	13.2	13.6	11.2	11.3	13.7

The renovations would include modifications to increase the adaptability of the space to meet future mission needs. New general-purpose laboratory/office facilities would be constructed to allow the reorganization or consolidation of staff into more efficient workgroups and to promote the interaction of interdisciplinary teams. New science and administrative facilities would be located for ease of access to the core of the site, and the site layout would be modified to provide a central campus with walkways.

The plan proposes facilities that would streamline user orientation and training, group support organizations and "community services" (such as bank, post office) into "one stop shopping," and would support the educational and recreational needs of users and their families. Adequate conference and videoconference facilities would be available for scientific meetings and discussions, and the library facilities would accommodate the state-of-the-art needs of the staff and users. All facility upgrades and new facilities would incorporate the appropriate information technology infrastructure; facilities would be available to receive, orient, and document visitors to the site, and to support community outreach and cultural resource programs. Demolishing older structures and renovating permanent buildings would eliminate ESH deficiencies. Consolidating support services would improve their efficiency, reduce operating costs, and improve customer services.

Real Property Maintenance: Funding levels for maintenance have slightly increased under BSA's management. A new category of funds for "recurring maintenance" allows the Laboratory to undertake critical maintenance tasks that are beyond the capability of the in-house shops. While this concept is sound, the funds for this capital renewal fall far short of the true need on a life cycle basis. This assertion is based on the results of a detailed study performed last year. It revealed that our preventive maintenance effort was only 59% of what it should be, and our capital renewal investment history (replacing building systems no longer economically serviceable) is even worse, at 39%.

If the Strategic Facility Plan projects were funded as proposed, our base preventive and corrective maintenance budgets would be adequate; however, we would still need an increase in our funding for capital renewal activities to prevent escalation of the deferred maintenance backlog. Similarly, under BSA, "non-capital" projects funds or "Operating Funded Projects" (some related to maintenance) increased to $2.7M in FY 00 and subsequently remained at that level. The Laboratory Director assigns these funds at the beginning of the fiscal year, which allows far more effective planning, prioritization, and use of them. Replacing WW II wood frame buildings with new, modern structures will eliminate the maintenance backlog associated with these structures, as well as the capital renewal projects that are needed over the next 10 years to sustain their operation. Similarly, the comprehensive renovation program we proposed for the permanent laboratory/office facilities will address the maintenance backlog for them.

An upgraded physical plant would reduce operating costs. Even at the same rate of G&A, there would be sufficient revenue to sustain the infrastructure.

The projects proposed for third party funding also would be removed from the maintenance effort and would be self-sustaining. As a result, we would project a flat maintenance budget over the ten-year planning period. The adequacy of this level will be reviewed annually over the planning period as new projects are implemented and RPV is adjusted. The goal is to ensure that any investments in new facilities are appropriately protected.

General Plant Projects (GPP): GPP projects presented in the Strategic Facility Plan were broken down into two parts: baseline GPP, and large projects referred to as "super GPP." To achieve BNL's infrastructure goals and objectives, a significant increase in GPP is required. It would be in the form of a modest rise in the GPP baseline over inflation, coupled with incremental funds to support the "super GPP" projects that have been identified and programmed over the planning period. Adding these components and averaging them out over the planning period, the GPP would have to double, increasing to approximately $12M/year in FY 02 dollars.

Line-item Construction: The bulk of the capital funds needed to meet the infrastructure objectives of the Laboratory would be funded through line item construction projects (programmatic and SLI) and third party financing

Many of the proposed projects will replace WWII wood structures and would generate an attractive return on investment (ROI) that results from increased staff productivity, reduced energy and maintenance costs, and the inherent efficiencies of consolidation (such as shared office equipment, administrative support, reduced vehicle needs). Furthermore, the overall physical plant would be smaller, since new space is expected to be less in total square feet than that demolished, so reducing site-related maintenance and operating costs. Ultimately, the driver for this investment is the positive impact it will have on the science and technology programs of the Laboratory.

Based on the Laboratory's strategic plan for science and technology, the permanent laboratory/office buildings (e.g., Chemistry, Biology, Medical, and Physics) are suitably configured and equipped to support science at Brookhaven well into the 21st century, provided that they are rehabilitated and modernized. A series of projects is proposed to rehabilitate such buildings. These structures are sound and have at least another 50 years of useful life, but interior finishes and mechanical and electrical systems require replacement.

A series of utility-related projects are proposed to address the continuing needs of the utility infrastructure and ensure that utility systems are appropriately reconfigured to support the projects proposed in this plan.

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Third-Party Funded Projects: BNL identified housing projects as the most likely candidates for third party funding. The Laboratory has 60-year-old short-term (dormitory & Guest House) and long-term (apartment and cottage) housing for users and guests. The housing stock is approximately 85% WW II wood frame construction (with the remainder mostly 35 years old) and is substandard, despite cosmetic improvements over the years. More housing is needed, since BNL is unable to fully accommodate the summer housing needs of the user community.

BNL is monitoring ORNL's attempts to execute an agreement allowing state- and corporate-backed development. In addition, BNL met with the Long Island Housing Partnership (LIHP) which works with state and local officials to act as facilitators in developing legislation and financial support for housing projects. Housing is rented to users and guests at market rates (verified by GSA), and the rental revenue should provide an attractive cash flow to a developer. The concept is similar to third-party Military Family Housing (MFH) construction that has been successful in the Department of Defense. The approach BNL is currently considering would have BSA contract for construction, with the successful offeror selected through a competitive request for proposal (RFP). Once the apartments were built and occupancy accepted by BNL, they could be made available by contract or lease arrangement from BSA to the developer to act as lessor on behalf of BNL. Alternately, BNL may choose to utilize its own on-site leasing services. An Expression of Interest document was published and a meeting was held in May 2002 to collect comments and gauge investors' interest in such projects.

A preliminary investigation into a project to construct a third-party funded laboratory/office building began recently.

9.0 Resource Projections

Table 11 - Laboratory Funding Summary ($ In Millions In Budget Authority)							
	FY 01	FY 02	FY 03*	FY 04*	FY 05**	FY 06**	FY 07**
DOE Effort	327.2	328.0	338.1	423.4	423.4	423.4	423.4
Work For Other Than DOE	41.0	44.2	45.3	43.4	43.4	43.4	43.4
Total Operating	**368.2**	**372.2**	**383.4**	**466.8**	**466.8**	**466.8**	**466.8**
Capital Equipment	32.3	29.3	21.6	32.8	32.8	32.8	32.8
Program Construction	46.0	49.0	63.7	44.6	69.7	88.8	40.6
General Purpose Equipment (GPE)	3.5	5.5	4.5	7.7	7.7	7.7	7.7
General Plant Projects (GPP)	6.1	6.1	6.1	6.5	6.5	6.5	6.5
TOTAL FUNDING	**456.1**	**462.1**	**479.3**	**558.4**	**583.5**	**602.6**	**554.4**
* ESCALATION FACTORS: FY2003 AND FY2004 AT 3.8% AND 3.3% ,RESPECTIVELY							
** CONSTANT FY2005 DOLLARS							

Table 12 - Laboratory Personnel Summary (Personnel In FTE)							
	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07
Direct							
DOE Effort	1203	1176	1120	1349	1349	1349	1349
Work For Other Than DOE	295	302	306	256	256	256	256
Total Direct	**1498**	**1478**	**1426**	**1605**	**1605**	**1605**	**1605**
Indirect							
Total Organizational Burden	187	163	173	174	174	174	174
LDRD and Program Development	49	57	41	28	28	28	28
Total Material Burden	72	72	78	78	78	78	78
Distributed/Allocated Services	549	606	76	586	586	586	586
IIDirect (G&A)	525	479	512	534	534	534	534
Total Indirect (G&A)	**1382**	**1377**	**880**	**1400**	**1400**	**1400**	**1400**
Total Laboratory Personnel	**2880**	**2855**	**2816**	**3005**	**3005**	**3005**	**3005**

Table 13 – Funding Summary By Assistant Secretarial Office ($ In Millions in Budget Authority)							
	FY 01	**FY 02**	**FY 03***	**FY 04***	**FY 05****	**FY 06****	**FY 07****
Director, Office Of Science							
Operating	248.0	232.0	229.0	304.4	304.4	304.4	304.4
Inventories	-3.6	-1.6	0.0	0.0	0.0	0.0	0.0
Capital Equipment	32.2	28.7	21.6	32.8	32.8	32.8	32.8
GPE	3.5	5.5	4.5	7.7	7.7	7.7	7.7
GPP	6.1	6.1	6.1	6.5	6.5	6.5	6.5
Construction	10.1	10.0	11.9	19.0	56.7	77.2	38.4
TOTAL	**296.3**	**280.7**	**273.1**	**370.4**	**408.1**	**428.6**	**389.8**
A/S Conservation & Renewable Energy							
Operating	6.2	6.6	8.4	9.9	9.9	9.9	9.9
Capital Equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL (Operating)	**6.3**	**6.6**	**8.4**	**9.9**	**9.9**	**9.9**	**9.9**
A/S Office of Energy Assurance							
Operating	**0.0**	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
A/S Environment, Safety & Health							
TOTAL (Operating)	**0.3**	**0.3**	**0.4**	**0.3**	**0.3**	**0.3**	**0.3**
A/S Nonprolif. &National Security							
TOTAL (Operating)	**32.0**	**50.1**	**56.2**	**57.8**	**57.8**	**57.8**	**57.8**
A/S Defense Programs							
TOTAL (Operating)	**0.0**	**1.5**	**0.8**	**0.9**	**0.9**	**0.9**	**0.9**
A/S, Environ. Restoration & Waste Mgmt.							
Operating	38.9	32.5	37.5	44.7	44.7	44.7	44.7
Capital Equipment	0.1	0.6	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	**39.0**	**33.1**	**37.5**	**44.7**	**44.7**	**44.7**	**44.7**
A/S Fossil Energy							
Operating	0.2	0.7	0.4	0.4	0.4	0.4	0.4
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	**0.2**	**0.7**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
Office of Nuclear Energy							
Operating	3.0	3.7	3.5	3.9	3.9	3.9	3.9
Construction	0.0	0.0	0.2	9.6	13.0	11.6	2.2
TOTAL	**3.0**	**3.7**	**3.7**	**13.5**	**16.9**	**15.5**	**6.1**
Office, Security& Emergency Mgmt.							
Operating	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	**1.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 13 – Funding Summary By Assistant Secretarial Office ($ In Millions in Budget Authority)							
	FY 01	**FY 02**	**FY 03***	**FY 04***	**FY 05****	**FY 06****	**FY 07****
Energy Information Administration							
TOTAL (Operating)	**0.2**	**1.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Office Of Chief Financial Officer							
TOTAL (Operating)	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Office Of Counter Intelligence							
TOTAL (Operating)	**1.0**	**0.8**	**1.8**	**1.0**	**1.0**	**1.0**	**1.0**
TOTALS-DOE PROGRAMS							
Operating	330.8	329.6	338.1	423.4	423.4	423.4	423.4
Inventories	-3.6	-1.6	0.0	0.0	0.0	0.0	0.0
Capital Equipment	32.3	29.3	21.6	32.8	32.8	32.8	32.8
Program Construction	10.8	10.1	12.1	28.6	69.7	88.8	40.6
GPE	3.5	5.5	4.5	7.7	7.7	7.7	7.7
GPP	6.1	6.1	6.1	6.5	6.5	6.5	6.5
TOTAL	**379.9**	**379.0**	**382.4**	**499.0**	**540.1**	**559.2**	**511.0**

* ESCALATION FACTORS: FY2003 AND FY2004 AT 3.8% AND 3.3% ,RESPECTIVELY
** CONSTANT FY2005 DOLLARS

Table 14 – Funding Summary – Work for Others ($ in Millions In Budget Authority)							
	FY 01	FY 02	FY 03*	FY 04*	FY 05**	FY 06**	FY 07**
Nuclear Regulatory Commission							
TOTAL (Operating)	**7.4**	**8.1**	**7.5**	**7.7**	**7.7**	**7.7**	**7.7**
Department Of Defense							
TOTAL (Operating)	**0.6**	**1.2**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
National Aeronautics and Space Administration							
Operating	1.5	2.1	2.1	2.2	2.2	2.2	2.2
Capital	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[(a)]Construction - Booster Appl. Facility	8.3	10.0	10.8	5.0	0.0	0.0	0.0
FUNDING TOTAL	**9.8**	**12.1**	**12.9**	**7.2**	**2.2**	**2.2**	**2.2**
Department Of State							
TOTAL (Operating)	**6.7**	**7.9**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**
National Science Foundation							
TOTAL (Operating)	**0.0**	**0.0**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**
Department Of Health And Human Services							
TOTAL (Operating)	**8.9**	**13.1**	**14.5**	**12.9**	**12.9**	**12.9**	**12.9**
Environmental Protection Agency							
TOTAL (Operating)	**1.8**	**1.3**	**2.1**	**2.0**	**2.0**	**2.0**	**2.0**
Other Federal Agencies							
TOTAL (Operating)	**1.0**	**1.0**	**1.1**	**1.3**	**1.3**	**1.3**	**1.3**
Other DOE Labs							
Operating	5.3	5.2	4.7	4.8	4.8	4.8	4.8
Capital	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction - SNS	26.9	32.3	40.8	11.0	0.0	0.0	0.0
TOTAL (Operating)	**32.2**	**37.5**	**45.5**	**15.8**	**4.8**	**4.8**	**4.8**
All Others							
TOTAL (Operating)	**7.8**	**12.0**	**8.6**	**7.9**	**7.9**	**7.9**	**7.9**
Totals-Work For Other Than DOE							
Operating	41.0	51.9	45.3	43.4	43.4	43.4	43.4
Construction	35.2	42.3	51.6	16.0	0.0	0.0	0.0
TOTAL (Operating)	**76.2**	**94.2**	**96.9**	**59.4**	**43.4**	**43.4**	**43.4**
Laboratory Totals							
Operating	371.8	351.6	381.7	466.8	466.8	466.8	466.8
Inventories	-2.9	-1.6	0.0	0.0	0.0	0.0	0.0
Capital Equipment	32.3	25.0	21.6	32.8	32.8	32.8	32.8

Table 14 – Funding Summary – Work for Others							
($ in Millions In Budget Authority)							
	FY 01	FY 02	FY 03*	FY 04*	FY 05**	FY 06**	FY 07**
Program Construction	46.0	52.3	63.7	66.6	85.2	54.8	26.8
GPE	3.5	5.5	4.5	7.7	7.7	7.7	7.7
GPP	6.1	6.1	6.1	6.5	6.5	6.5	6.5
TOTAL	**456.8**	**438.9**	**477.6**	**580.4**	**599.0**	**568.6**	**540.6**

(a) Funded
*   ESCALATION FACTORS: FY2003 AND FY2004 AT 3.8% AND 3.3% ,RESPECTIVELY
** CONSTANT FY2005 DOLLARS

Table 15 - Personnel By Assistant Secretarial Office							
(Personnel In FTE)							
	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07
Department Of Energy Programs (FTEs)							
Director, Office Of Science	1089	1041	973	1204	1204	1204	1204
A/S Conservation & Renewable Energy	19	19	22	24	24	24	24
A/S Office Of Energy Assurance	0	0	0	0	0	0	0
A/S Environment, Safety & Health	2	2	2	2	2	2	2
A/S, Nuclear Energy	8	10	10	8	8	8	8
A/S, Nonproliferation And National Security	24	26	27	27	27	27	27
A/S, Office Of Counter Intelligence	5	4	5	5	5	5	5
A/S, Defense Programs	0	4	4	4	4	4	4
A/S Environmental Restoration & Waste Management	53	68	75	73	73	73	73
A/S, Fossil Energy	0	2	2	2	2	2	2
Office Of Security & Emergency Operation	3	0	0	0	0	0	0
Energy Information Administration	0	0	0	0	0	0	0
Office Of Chief Financial Officer	0	0	0	0	0	0	0
TOTAL: DOE Programs	**1203**	**1176**	**1120**	**1349**	**1349**	**1349**	**1349**

Table 16 - Personnel - Work for Others (Personnel In FTE)							
	FY 01	**FY 02**	**FY 03**	**FY 04**	**FY 05**	**FY 06**	**FY 07**
Work For Other Than DOE (FTEs)							
Nuclear Regulatory Commission	25	25	26	26	26	26	26
Department Of Defense	2	2	0	0	0	0	0
Department Of State	7	7	8	8	8	8	8
Nat'l Aeronautics And Space Administration	29	38	33	23	23	23	23
Department Of Health And Human Services	47	40	49	48	48	48	48
National Science Foundation	0	0	0	0	0	0	0
Environmental Protection Agency	3	3	3	3	3	3	3
Other Federal Agencies	1	4	4	4	4	4	4
Other DOE Labs	121	121	115	72	72	72	72
All Others	60	62	68	72	72	72	72
TOTAL: Work For Other Than DOE	**295**	**302**	**306**	**256**	**256**	**256**	**256**
Laboratory Personnel Summary							
Total Laboratory-Direct	**1498**	**1478**	**1426**	**1605**	**1605**	**1605**	**1605**
Indirect							
Total Organizational Burden	187	163	173	174	174	174	174
Laboratory Directed R&D	49	57	41	28	28	28	28
Total Material Burden	72	72	78	78	78	78	78
Distributed/Allocated Services	549	606	586	586	586	586	586
IIDirect (G&A)	525	479	512	534	534	534	534
TOTAL: Laboratory-Personnel	**2880**	**2855**	**2816**	**3005**	**3005**	**3005**	**3005**

Table 17 - Funding By Assistant Secretarial Level Office – DOE Office of Science (In Millions In Budget Authority)							
	FY 01	**FY 02**	**FY 03***	**FY 04***	**FY 05****	**FY 06****	**FY 07****
OFFICE OF SCIENCE							
KA-05 Facility Operations							
Operating	12.3	9.9	1.9	13.0	13.0	13.0	13.0
Changes In Inventories	-0.7	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	10.2	10.9	5.5	4.6	4.6	4.6	4.6
TOTAL FUNDING	**21.8**	**20.8**	**7.4**	**17.6**	**17.6**	**17.6**	**17.6**
DIRECT PERSONNEL	91	84	41	57	57	57	57
KA-04 Research And Technology							
Operating	16.5	16.6	15.0	22.3	22.3	22.3	22.3
Capital Equipment	0.0	1.7	1.3	2.9	2.9	2.9	2.9
TOTAL FUNDING	**16.5**	**18.3**	**16.3**	**25.2**	**25.2**	**25.2**	**25.2**
DIRECT PERSONNEL	80	84	69	106	106	106	106
KA High Energy Physics - TOTALS							
Operating	28.8	26.5	16.9	35.3	35.3	35.3	35.3
Changes In Inventories	-0.7	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	10.2	12.6	6.8	7.5	7.5	7.5	7.5
TOTAL FUNDING	**38.3**	**39.1**	**23.7**	**42.8**	**42.8**	**42.8**	**42.8**
DIRECT PERSONNEL	**171**	**168**	**110**	**163**	**163**	**163**	**163**
KB-01 Medium Energy Physics							
Operating	5.0	4.2	3.0	5.1	5.1	5.1	5.1
Capital Equipment	0.1	0.2	0.1	0.6	0.6	0.6	0.6
TOTAL FUNDING	**5.1**	**4.4**	**3.1**	**5.7**	**5.7**	**5.7**	**5.7**
DIRECT PERSONNEL	22	18	14	23	23	23	23
KB-02 Heavy Ion Physics							
Physics Research	6.0	6.0	6.2	7.9	7.9	7.9	7.9
Facility Operations							
AGS/TVDG Operations							
RHIC Operation	72.0	72.2	83.0	98.8	98.8	98.8	98.8
RHIC Expt'l Support	23.8	23.9	26.3	30.9	30.9	30.9	30.9
Other Operation	5.9	5.9	0.0	6.0	6.0	6.0	6.0
Total Facility Operations	101.7	102.0	109.3	135.7	135.7	135.7	135.7
Total Operating	107.7	108.0	115.5	143.6	143.6	143.6	143.6
Capital Equipment							
Add. Exp. Equip.	4.3	3.1	0.0	0.0	0.0	0.0	0.0
RHIC Oper. Equip.	1.7	1.1	3.8	4.2	4.2	4.2	4.2
RHIC Exp. Support-Equipment	4.9	3.7	4.2	6.7	6.7	6.7	6.7
GPE	3.5	5.5	4.5	7.7	7.7	7.7	7.7
Other Programmatic	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Capital	14.5	13.4	12.5	18.6	18.6	18.6	18.6
(GPP)	6.1	6.1	6.1	6.5	6.5	6.5	6.5

Table 17 - Funding By Assistant Secretarial Level Office – DOE Office of Science (In Millions In Budget Authority)							
	FY 01	**FY 02**	**FY 03***	**FY 04***	**FY 05****	**FY 06****	**FY 07****
Construction (AIP)	2.3	2.5	2.9	6.3	6.3	6.3	6.3
Total Construction	8.4	8.6	9.0	12.8	12.8	12.8	12.8
TOTAL FUNDING	**130.6**	**130.0**	**137.0**	**175.0**	**175.0**	**175.0**	**175.0**
DIRECT PERSONNEL	460	456	457	515	515	515	515
KB-03 Nuclear Theory							
TOTAL (Operating)	**4.4**	**5.0**	**4.3**	**5.1**	**5.1**	**5.1**	**5.1**
DIRECT PERSONNEL	21	22	16	22	22	22	22
KB-04 Low Energy Physics							
Operating	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Capital Equipment	0.0	0.1	0.1	0.1	0.1	0.1	0.1
TOTAL FUNDING	**0.7**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**
DIRECT PERSONNEL	3	2	4	4	4	4	4
KB Nuclear Physics – TOTALS							
Operating	117.8	117.9	123.5	154.5	154.5	154.5	154.5
Capital Equipment	14.6	13.7	12.7	19.3	19.3	19.3	19.3
Construction							
GPP	6.1	6.1	6.1	6.5	6.5	6.5	6.5
Construction (AIP)	2.3	2.5	2.9	6.3	6.3	6.3	6.3
Total Construction	8.4	8.6	9.0	12.8	12.8	12.8	12.8
TOTAL FUNDING	**140.8**	**140.2**	**145.2**	**186.6**	**186.6**	**186.6**	**186.6**
DIRECT PERSONNEL	506	498	491	564	564	564	564
KC-02 Materials Sciences							
Operating							
Research	11.0	11.5	10.9	13.9	13.9	13.9	13.9
NSLS Operations	23.0	23.2	30.9	46.5	46.5	46.5	46.5
HFBR Operations	18.2	1.3	0.0	0.0	0.0	0.0	0.0
Cntr. For Func. Nanomaterials Jump Start	0.0	0.0	1.7	0.0	0.0	0.0	0.0
Total Operating	52.2	36.0	43.5	60.4	60.4	60.4	60.4
Changes In Inventories	-2.9	-1.6					
Capital Equipment	4.3	3.6	4.5	8.4	8.4	8.4	8.4
Construction							
[b] Cntr. For Functional Nanomaterials	0.0	0.0	0.0	4.3	27.7	42.0	11.0
Construction (AIP)	1.4	1.4	1.4	1.7	1.7	1.7	1.7
Total Construction	1.4	1.4	1.4	6.0	29.4	43.7	12.7
TOTAL FUNDING	**55.0**	**39.4**	**49.4**	**74.8**	**98.2**	**112.5**	**81.5**
DIRECT PERSONNEL	215	184	182	260	260	260	260

Table 17 - Funding By Assistant Secretarial Level Office – DOE Office of Science (In Millions In Budget Authority)							
	FY 01	**FY 02**	**FY 03***	**FY 04***	**FY 05****	**FY 06****	**FY 07****
KC-03 Chemical Sciences							
Research (Operating)	9.9	9.9	9.5	14.3	14.3	14.3	14.3
NSLS Operations	7.3	7.2	0.0	0.0	0.0	0.0	0.0
Total Operating	17.2	17.1	9.5	14.3	14.3	14.3	14.3
Capital Equipment	2.1	1.3	1.0	3.6	3.6	3.6	3.6
TOTAL FUNDING	**19.3**	**18.4**	**10.5**	**17.9**	**17.9**	**17.9**	**17.9**
DIRECT PERSONNEL	38	34	42	58	58	58	58
KC-04 Engineering And Geosciences							
Operating	0.3	0.0	0.0	0.2	0.2	0.2	0.2
Capital Equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL FUNDING	**0.4**	**0.0**	**0.0**	**0.2**	**0.2**	**0.2**	**0.2**
DIRECT PERSONNEL	2	0	0	1	1	1	1
KC-06 Energy Biosciences							
Operating	1.2	1.1	1.0	1.0	1.0	1.0	1.0
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1
TOTAL FUNDING	**1.3**	**1.2**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**
DIRECT PERSONNEL	4	4	3	3	3	3	3
KC - Basic Energy Sciences – TOTALS							
Research (Operating)	22.4	22.5	21.4	29.4	29.4	29.4	29.4
NSLS Operations	30.3	30.4	30.9	46.5	46.5	46.5	46.5
HFBR Operations	18.2	1.3	0.0	0.0	0.0	0.0	0.0
Cntr. For Func. Nanomaterials Jump Start	0.0	0.0	1.7	0.0	0.0	0.0	0.0
Total Operating	70.9	54.2	54.0	75.9	75.9	75.9	75.9
Changes In Inventories	-2.9	-1.6	0.0	0.0	0.0	0.0	0.0
Capital Equipment	6.6	5.0	5.6	12.1	12.1	12.1	12.1
Construction							
[(a)]Cntr. For Functional Nanomaterials (B)	0.0	0.0	0.0	4.3	27.7	42.0	11.0
Construction (AIP)	1.4	1.4	1.4	1.7	1.7	1.7	1.7
Total Construction	1.4	1.4	1.4	6.0	29.4	43.7	12.7
TOTAL FUNDING	**76.0**	**59.0**	**61.0**	**94.0**	**117.4**	**131.7**	**100.7**
DIRECT PERSONNEL	259	222	227	322	322	322	322
KG - Multiprogram Energy Labs – TOTALS							
User Research Center	0.0	0.0	0.0	1.6	6.8	7.0	0.0
Construction	6.4	6.1	7.6	5.1	14.2	20.2	19.4
TOTAL FUNDING	**6.4**	**6.1**	**7.6**	**6.7**	**21.0**	**27.2**	**19.4**
DIRECT PERSONNEL	0	0	0	0	0	0	0

Table 17 – Funding By Assistant Secretarial Level Office – DOE Office of Science (In Millions In Budget Authority)							
	FY 01	**FY 02**	**FY 03***	**FY 04***	**FY 05****	**FY 06****	**FY 07****
KP - Biological & Environmental Research – TOTALS							
Research (Operating)	19.3	20.1	20.8	23.5	23.5	23.5	23.5
Capital Equipment	4.3	2.9	0.6	1.2	1.2	1.2	1.2
TOTAL FUNDING	**23.6**	**23.0**	**21.4**	**24.7**	**24.7**	**24.7**	**24.7**
DIRECT PERSONNEL	74	76	74	81	81	81	81
KJ - Computation and Technology Research - TOTALS							
TOTAL (Operating)	**2.2**	**1.4**	**1.1**	**1.6**	**1.6**	**1.6**	**1.6**
DIRECT PERSONNEL	8	7	4	4	4	4	4
KX - University and Science Education - TOTALS							
TOTAL (Operating)	**0.4**	**0.4**	**0.7**	**1.5**	**1.5**	**1.5**	**1.5**
DIRECT PERSONNEL	0	0	0	0	0	0	0
KH - Facilities & Infrastructure - TOTALS							
TOTAL (Operating)	**0.0**	**1.4**	**1.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	0	0	0	0	0	0	0
FS - Safeguards & Security Science - TOTALS							
Operating	8.6	10.1	11.0	12.1	12.1	12.1	12.1
Capital Equipment			0.4	0.4	0.4	0.4	0.4
TOTAL FUNDING	**8.6**	**10.1**	**11.4**	**12.5**	**12.5**	**12.5**	**12.5**
DIRECT PERSONNEL	71	70	67	70	70	70	70
TOTALS – DOE OFFICE OF SCIENCE							
Total Operating	248.0	232.0	229.0	304.4	304.4	304.4	304.4
Change In Inventories	-3.6	-1.6	0.0	0.0	0.0	0.0	0.0
Capital Equipment	32.2	28.7	21.6	32.8	32.8	32.8	32.8
GPE	3.5	5.5	4.5	7.7	7.7	7.7	7.7
GPP	6.1	6.1	6.1	6.5	6.5	6.5	6.5
Construction	10.1	10.0	11.9	19.0	56.7	77.2	38.4
TOTAL FUNDING	**296.3**	**280.7**	**273.1**	**370.4**	**408.1**	**428.6**	**389.8**
DIRECT PERSONNEL	**1089**	**1041**	**973**	**1204**	**1204**	**1204**	**1204**

* ESCALATION FACTORS: FY2003 AND FY2004 AT 3.8% AND 3.3%, RESPECTIVELY
** CONSTANT FY2005 DOLLARS; [(a)] PROPOSED

Table 18 - Funding By Assistant Secretarial Level Office – Other DOE Programs (In Millions In Budget Authority)							
	FY 01	FY 02	FY 03*	FY 04*	FY 05**	FY 06**	FY 07**
A/S Conservation & Renewable Energy							
EB - Solar and Renewable Research Technologies							
TOTAL (Operating)	**2.0**	**1.8**	**2.1**	**2.1**	**2.1**	**2.1**	**2.1**
DIRECT PERSONNEL	8	8	8	8	8	8	8
EC - Buildings and Community Systems							
Operating	1.3	0.5	0.6	0.6	0.6	0.6	0.6
Capital Equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL FUNDING	**1.4**	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
DIRECT PERSONNEL	5	1	2	2	2	2	2
EE – Transportation							
TOTAL (Operating)	**2.6**	**3.4**	**4.4**	**4.9**	**4.9**	**4.9**	**4.9**
DIRECT PERSONNEL	5	6	7	7	7	7	7
EH - Policy And Management (EERE)							
TOTAL (Operating)	**0.1**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
DIRECT PERSONNEL	1	1	1	1	1	1	1
EO - Power Technology							
TOTAL (Operating)	**0.0**	**0.6**	**1.0**	**2.0**	**2.0**	**2.0**	**2.0**
DIRECT PERSONNEL	0	3	4	6	6	6	6
WB - In-House Energy Management							
Operating	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.7	0.1					
TOTAL FUNDING	**0.9**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	0	0	0	0	0	0	0
Conservation & Renewable Energy - TOTALS							
Operating	6.2	6.6	8.4	9.9	9.9	9.9	9.9
Construction	0.7	0.1	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL FUNDING	**7.0**	**6.7**	**8.4**	**9.9**	**9.9**	**9.9**	**9.9**
DIRECT PERSONNEL	19	19	22	24	24	24	24
A/S Environment, Safety & Health							
HC – Environment, Safety And Health (Non-Defense)							
TOTAL (Operating)	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
DIRECT PERSONNEL	1	1	1	1	1	1	1
HD - Environment, Safety And Health (Defense)							
TOTAL (Operating)	**0.2**	**0.1**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**
DIRECT PERSONNEL	1	1	1	1	1	1	1
Environment, Safety and Health - TOTALS							
TOTAL (Operating)	**0.3**	**0.3**	**0.4**	**0.3**	**0.3**	**0.3**	**0.3**

Table 18 - Funding By Assistant Secretarial Level Office – Other DOE Programs							
(In Millions In Budget Authority)							
	FY 01	**FY 02**	**FY 03***	**FY 04***	**FY 05****	**FY 06****	**FY 07****
DIRECT PERSONNEL	2	2	2	2	2	2	2
A/S Nonproliferation and National Security							
PS Program Direction –Nat'nl Nuc. Sec. Admin.							
TOTAL (Operating)	**0.0**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	0	0	0	0	0	0	0
NN - Nonproliferation and National Security Program Direction							
TOTAL (Operating)	**32.0**	**50.0**	**56.2**	**57.8**	**57.8**	**57.8**	**57.8**
DIRECT PERSONNEL	24	26	27	27	27	27	27
A/S Nonproliferation and National Security -TOTALS							
TOTAL (Operating)	**32.0**	**50.1**	**56.2**	**57.8**	**57.8**	**57.8**	**57.8**
DIRECT PERSONNEL	24	26	27	27	27	27	27
A/S Office Of Counter Intelligence - TOTAL							
CN - Counter Intelligence							
TOTAL (Operating)	**1.0**	**0.8**	**1.8**	**1.0**	**1.0**	**1.0**	**1.0**
DIRECT PERSONNEL	5	4	5	5	5	5	5
A/S Defense Programs - TOTAL							
DP - Other Weapons Activities							
TOTAL (Operating)	**0.0**	**1.5**	**0.8**	**0.9**	**0.9**	**0.9**	**0.9**
PERSONNEL	0	4	4	4	4	4	4
A/S Environmental Restoration And Waste Management - TOTALS							
EW Environ. Restoration And Waste Mgmt.							
Operating	38.9	32.5	37.5	44.7	44.7	44.7	44.7
Capital Equipment	0.1	0.6	0.0	0.0	0.0	0.0	00
TOTAL FUNDING	**39.0**	**33.1**	**37.5**	**44.7**	**44.7**	**44.7**	**44.7**
DIRECT PERSONNEL	53	68	75	73	73	73	73
A/S Fossil Energy							
AA Coal							
TOTAL (Operating)	**0.1**	**0.3**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
DIRECT PERSONNEL	0	1	1	1	1	1	1
AB GAS	0.0	0.2	0.0	0.0	0.0	0.0	0.0
TOTAL (Operating)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DIRECT PERSONNEL	0	0	0	0	0	0	0
AC – Petroleum							
TOTAL (Operating)	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
DIRECT PERSONNEL	0	1	1	1	1	1	1

Table 18 - Funding By Assistant Secretarial Level Office – Other DOE Programs (In Millions In Budget Authority)							
	FY 01	**FY 02**	**FY 03***	**FY 04***	**FY 05****	**FY 06****	**FY 07****
Fossil Energy – TOTALS							
TOTAL (Operating)	**0.2**	**0.7**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
DIRECT PERSONNEL	0	2	2	2	2	2	2
Office of Nuclear Energy							
ST Isotope Prod. And Distribution Program							
Operating	2.4	2.8	2.6	3.3	3.3	3.3	3.3
(b) Cyclotron Isotope Research Center	0.0	0.0	0.2	9.6	13.0	11.6	2.2
TOTAL FUNDING	**2.4**	**2.8**	**2.8**	**12.9**	**16.3**	**14.9**	**5.5**
DIRECT PERSONNEL	7	7	6	6	6	6	6
AF - Nuclear Energy Research & Development							
TOTAL (Operating)	**0.6**	**0.9**	**0.9**	**0.6**	**0.6**	**0.6**	**0.6**
DIRECT PERSONNEL	1	3	4	2	2	2	2
Office Of Nuclear Energy – TOTAL							
Operating	3.0	3.7	3.5	3.9	3.9	3.9	3.9
Construction	0.0	0.0	0.2	9.6	13.0	11.6	2.2
TOTAL FUNDING	**3.0**	**3.7**	**3.7**	**13.5**	**16.9**	**15.5**	**6.1**
PERSONNEL	8	10	10	8	8	8	8
Office Of Security And Emergency Operation							
SO - Security And Emergency Management							
TOTAL (Operating)	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	1	0	0	0	0	0	0
GD - Nuclear Safeguards & Security							
TOTAL (Operating)	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	0	0	0	0	0	0	0
ND - Emergency Management							
TOTAL (Operating)	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	2	0	0	0	0	0	0
Office of Security and Emergency Management – TOTAL							
TOTAL (Operating)	**1.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	3	0	0	0	0	0	0
Energy Information Administration – TOTAL **TA - National Energy Information System**							
TOTAL (Operating)	**0.2**	**1.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
DIRECT PERSONNEL	0	0	0	0	0	0	0

* ESCALATION FACTORS: FY2003 AND FY2004 AT 3.8% AND 3.3%, RESPECTIVELY
** CONSTANT FY2005 DOLLARS

Table 19 - Work For Others Programs ($In Millions In Budget Authority)							
	FY 01	**FY 02**	**FY 03***	**FY 04***	**FY 05****	**FY 06****	**FY 07****
Nuclear Regulatory Commission							
Nuclear Reactor Regulation							
Operating	**2.4**	**2.1**	**2.5**	**2.3**	**2.3**	**2.3**	**2.3**
DIRECT PERSONNEL	8	8	7	7	7	7	7
Nuclear Regulatory Research							
Operating	**4.0**	**4.6**	**3.9**	**4.3**	**4.3**	**4.3**	**4.3**
DIRECT PERSONNEL	14	14	15	15	15	15	15
Commission And Staff Offices							
Operating	**1.0**	**1.9**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**
DIRECT PERSONNEL	3	3	4	4	4	4	4
TOTAL (Operating)	**7.4**	**8.6**	**7.5**	**7.7**	**7.7**	**7.7**	**7.7**
DIRECT PERSONNEL	25	25	26	26	26	26	26
Department Of State							
TOTAL (Operating)	**6.7**	**4.7**	**4.4**	**4.4**	**4.4**	**4.4**	**4.4**
DIRECT PERSONNEL	7	7	8	8	8	8	8
Department Of Defense							
TOTAL (Operating)	**0.6**	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
DIRECT PERSONNEL	2	2	0	0	0	0	0
National Aeronautics and Space Administration							
Operating	1.5	2.1	2.1	2.2	2.2	2.2	2.2
Capital	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[(a)] Construction – Booster Application Facility	8.3	9.5	10.8	5.0	0.0	0.0	0.0
TOTAL FUNDING	**9.8**	**11.6**	**12.9**	**7.2**	**2.2**	**2.2**	**2.2**
DIRECT PERSONNEL	29	38	33	23	23	23	23
Department Of Health & Human Services							
TOTAL (Operating)	**8.9**	**11.1**	**14.5**	**12.9**	**12.9**	**12.9**	**12.9**
DIRECT PERSONNEL	47	40	49	48	48	48	48
National Science Foundation							
TOTAL (Operating)	**0.0**	**0.0**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**
DIRECT PERSONNEL	0	0	0	0	0	0	0
Environmental Protection Agency							
TOTAL (Operating)	**1.8**	**1.8**	**2.1**	**2.0**	**2.0**	**2.0**	**2.0**
DIRECT PERSONNEL	3	3	3	3	3	3	3

Table 19 - Work For Others Programs
($In Millions In Budget Authority)

	FY 01	FY 02	FY 03*	FY 04*	FY 05**	FY 06**	FY 07**
Other Federal Agencies							
TOTAL (Operating)	**1.0**	**0.6**	**1.1**	**1.3**	**1.3**	**1.3**	**1.3**
DIRECT PERSONNEL	1	4	4	4	4	4	4
Other DOE Laboratories							
Operating	5.3	5.5	4.7	4.8	4.8	4.8	4.8
Capital	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction - SNS.	26.9	29.4	40.8	11.0	0.0	0.0	0.0
TOTAL FUNDING	**32.2**	**34.9**	**45.5**	**15.8**	**4.8**	**4.8**	**4.8**
DIRECT PERSONNEL	121	121	115	72	72	72	72
All Others							
TOTAL (Operating)	**7.8**	**9.5**	**8.6**	**7.9**	**7.9**	**7.9**	**7.9**
DIRECT PERSONNEL ***	**60**	**62**	**68**	**72**	**72**	**72**	**72**

* ESCALATION FACTORS: FY2003 AND FY2004 AT 3.8% AND 3.3%, RESPECTIVELY
** CONSTANT FY2005 DOLLARS - Note: (1)Dept of State amt corrected from $5M to $4.7M. (2) State agency $.5M moved from other Federal agency to All other category.
*** Includes FTE's from Non-Reportable Programs, (a) Funded.

Table 20 - Laboratory Major Programmatic Construction Projects ($ In Millions In Budget Authority)								
		Funded		Budgeted		Proposed		
	TEC	FY01	FY02	FY03	FY04	FY05	FY06	FY07
Program Related – SC								
Accelerator Improvement Projects (KB)		2.3	2.5	2.9	6.3	6.3	6.3	6.3
Accelerator Improvement Projects (KC)		1.4	1.4	1.4	1.7	1.7	1.7	1.7
General Plant Projects (KB)		6.1	6.1	6.1	6.4	6.7	7.1	7.4
Total		**9.8**	**10.0**	**10.4**	**14.4**	**14.7**	**15.1**	**15.4**
Program Related - WFO - NASA								
Booster Applications Facility (BAF)	35.4	11.5	10.9	4.4				
Proposed Construction – NE								
Cyclotron Isotope Research Center	36.5				9.6	13.0	11.6	2.2
Proposed Construction – SC								
Center for Funct. Nanomaterials (KC)(AA1D0005)	85.0				4.1	22.9	42.8	15.2
Total		**11.5**	**10.9**	**4.4**	**13.7**	**35.9**	**54.4**	**17.4**
Under Evaluation								
RHIC II/eRHIC								
Upgrades to the NSLS								
Super Neutrino Beam								
Total Funded Program Construction		**21.3**	**20.9**					
Total Budgeted Program Construction				**14.8**	**28.1**			
Total Proposed Program Construction						**50.6**	**69.5**	**32.8**

Table 21 - Laboratory Major SLI Construction Projects ($ In Millions In Budget Authority)									
			Funded		Budgeted		Proposed		
SLI Projects	Project Type	TEC	FY01	FY02	FY03	FY04	FY05	FY06	FY07
Funded/Budgeted									
Electrical System Mods Ph. I (N98D0011)	3	5.7	1.0						
Sanitary Sys Upgrade Ph.III (A96D0029)	1	6.5	3.0						
Electrical System Mods Ph. II (N98D0022)	1	6.8	0.6	3.3	2.9				
Ground & Surface Water (A93D0340)	1	6.1	1.9	2.8	1.4				
Total			**6.5**	**6.1**	**4.3**				
Proposed - KG01									
Research Support Building–Ph I (AA0D0030)	5	18.2			3.3	5.1	9.8		
Energy Science Building (N98D0015)	5	18.4					1.8	7.7	8.9
User Research Building (N98D0015)	5	15.4				1.6	6.8	7.0	
Multi-Program Science Lab Renovation (AA3D0002)	2	15.0					1.6	7.5	5.9
Research Support Cnter–Ph II (AA1D0006)	5	18.2							1.6
Chilled Water Facility – Ph II (AA3D0002)	3,5	9.0					1.0	5.0	3.0
Total					**3.3**	**6.7**	**21.0**	**27.2**	**19.4**
Proposed - KG02									
None									
Total GPF Funded Construction			**6.5**	**6.1**					
Total GPF Budgeted Construction					**7.6**	**6.7**			
Total GPF Proposed Construction							**21.0**	**27.2**	**19.4**
SLI Project Types: 1. ES&H Support, 2. Building Rehabilitation/Upgrades, 3. Utility System Rehabilitation/Upgrades, 4. Roads and OSF Rehabilitation/Upgrades, 5. New Building									

Table 22 - Environmental, Safety, Health And Infrastructure Resource Projection (Costs In Millions)						
Funding	**FY01**	**FY02**	**FY03**	**FY04**	**FY05**	**FY06**
ESH Operating						
Laboratory (OFP/G&A)	2.9	3.3	3.0	(a)	(a)	(a)
Department & Division	36.8	37.1	37.5	54.6	54.8	55.0
ESH Capital Equipment	0.4	0.2	0.3	0.3	0.3	0.3
ESH Line Item	5.9	4.1	0.0	0.0	0.0	0.0
ESH GPP						
KA	0.0	0.0	0.0	(a)	(a)	(a)
KB	2.1	3.6	1.1	(a)	(a)	(a)
KC	0.0	0.0	0.0	(a)	(a)	(a)
KP	0.0	0.0	0.0	(a)	(a)	(a)
ESH AIP						
KA	0.0	0.0	0.0	(a)	(a)	(a)
KB	0.0	0.0	0.0	(a)	(a)	(a)
KC	0.0	0.0	0.1	(a)	(a)	(a)
KP	0.0	0.0	0.0	(a)	(a)	(a)
Infra. Operating (Space/G&A)	16.7	16.7	16.7	(a)	(a)	(a)
Infrastructure Line Item	0.8	3.0	6.6	22.0	50.4	51.0
Infrastructure GPP	3.1	8.1	4.3	(a)	(a)	(a)
Environmental Management (EM) Funded						
Remedial Actions	14.5	17.9	16.0	17.5	23.3	26.7
BGRR D&D EM-40	1.3	3.6	6.9	5.3	9.8	6.9
Boneyard Waste Disposal	3.2	2.7				
Program Management	3.1	3.0	3.0	2.5	2.9	2.4
BGRR D&D: Office of Science	4.9	0.2				
Waste Management Operations[b]	6.7	6.0	6.0	6.0	6.0	6.0
[a] To be determined						
[b] Supported by the Office of Science starting in FY 01 ending in FY 03						

Appendix A: Field Work Proposal

The Field Work Proposals are listed by DOE Mission, Goal, and Challenge. Several Field Work Proposals will be listed more than once, since the research contributes to more than one area.

Brookhaven National Laboratory

MISSION: SCIENCE AND TECHNOLOGY		
B & R	*PROGRAM TITLE*	*PRINCIPAL INVESTIGATOR*
Exploring Energy and Matter - Building Blocks from Atoms to Life		
KC-02-01-03	Mechanisms of Metal Environment Interactions	Isaacs, H.
KC-02-02-01	Neutron Scattering	Tranquada, J.
KC-02-02-01	X-Ray Scattering	Gibbs, D.
KC-02-02-02	Charge Inhomogeneity in Correlated Electron Systems	Gibbs, D.
KC-02-02-02	Electron Spectroscopy	Johnson, P.
KC-02-02-03	Condensed Matter Theory	Weinert, M.
KC-03-01-01	Injection of Electrons and Holes into Nanostructures	Creutz, C., Miller, J., Newton, M.
KC-03-01-02	Universal Imaging Studies of Chemical Physics	Suits, A.
KC-03-02-01	Catalysis on the Nanoscale: Preparation, Characterization and Reactivity of Metal-Based Nanostructures	White, M., Hrbek, J., Muckerman, J. T.
KC-06-00-00	Molecular Plant Genetics	Burr, B
KP-11-02-01	Diversity, Structure, and Functional Interdependence of Microbial Communities in the Plant Rhizosphere	Dunn, J.; van der Lelie, D. and others
KP-14-01-06	Protein Scaffolds and Labeling Strategies for Molecular Imaging	Freimuth, P. and others
KA-04-01-01	Research	Littenberg, L., Gordon, H. and others
KA-05-02-03	U.S. ATLAS Project	Gordon, H.
KB-01-01-02	Spin and Nuclear Structure Investigations with Hadronic Probes	Bunce, J.
KB-01-01-02	Laser Electron Gamma Source	Sandorfi, A
KB-02-01-02	Heavy Ion Research	Chasman, C. and Remsberg, L
KB-02-02-01	RHIC Experimental Operations	Aronson, S. and others
KB-03-01-02	Nuclear Theory	McLerran, T.
KC-02-02-01	X-ray Scattering	Gibbs, D.
KC-02-02-01	Powder Diffraction	Vogt, L..
KC-02-02-01	Neutron Scattering	Tranquada, J.
KC-02-02-02	Charge Inhomogeneity in Correlated Electron Systems	Gibbs, D.
KC-02-02-02	Electron Spectroscopy	Johnson, P.
KC-02-02-03	Condensed Matter Theory	Weinert, M.
KC-03-02-01	Review of HFIR Safety Analysis Report	Higgins, J.
KP-11-01-01A	Analysis of Human Proteins Induced in Response to Ionizing Radiation	Studier, W.
KP-11-01-01B	Operation and Development of the Scanning Transmission Electron Microscopy Facility	Wall, J.
KP-11-03-01	Genome Sequencing and Analysis	Dunn, J.
KB-02-01-02	Heavy Ion Research	Chasman, C. and Remsberg, L.
KB-04-01-02	Solar Neutrino Research	Hahn, R.
Extraordinary Tools for Extraordinary Science - National Assets for Multidisciplinary Research		
KC-02-04-011	Optics Systems for Synchrotron Radiation Applications	Takacs, P.
KC-03-02-01	Review of HFIR Safety Analysis Report	Higgins, J.
KJ-02-00	Office of Science Laboratory Technology Research Program	Bogosian, M.
KP-11-01-01A	Non-Homogeneous End-Joining DNA Repair: Characterization of Protein Structures and Complexes	Anderson, C.
KX-02-01	Science Education Programs	Murfin, B.
KA-04-01-01	U.S. ATLAS Computing	Gibbard, B. and Wenaus, T.
KA-04-03-01	Superconductor R&D and Testing	Sampson, W.
KA-04-03-01	Advanced Accelerator Research and Development - Muon Collider	Palmer, R.
KA-04-03-01	Accelerator Magnet R&D	Gupta, R.
KA-04-03-01	Accelerator Test Facility	Ben-Zvi, I.
KA-04-03-02	Experimental Facilities Research and Development	Gordon, H.
KA-05-02-01	U.S. LHC Accelerator Research Collaboration	Willen, E.. and Ghosh, A.
KA-05-02-03	U.S. ATLAS Project	Gordon, H., Lissauer, D. and others
KB-02-01-02	Experimental Equipment for RHIC Research	Ludlam, T.
KB-02-02-01	RHIC Collider Accelerator Operations	Roser, T.
KB-02-02-03	Other Capital Equipment Not Related to Construction	
KC-02-02-01	Neutron Instrument Development and User Support	Hastings, J.
KC-02-02-02	Soft X-Ray Speckle	Kao, C-C
KC-02-04-011	National Synchrotron Light Source Operations and Development	Dierker, S.
KP-11-01-01	NSLS Structural Biology Facility Operation	Sweet, R.
KP-11-01-01	Biophysical Instrumentation Research	Radeka, V. and Smith, G.

MISSION: SCIENCE AND TECHNOLOGY		
B & R	PROGRAM TITLE	PRINCIPAL INVESTIGATOR
KP-11-01-01A	Operations and Development of the Scanning Transmission Electron Microscope Facility	Wall, J.
KP-14-01-04	Functional and Physiologic Magnetic Resonance	Ernst, T.
KP-14-01-04A	Physiological Imaging	Volkow, N.
ST	CIRC CONSTRUCTION	
KA-04-01-01	U.S. ATLAS Computing	Gibbard, B. and Wenaus, T.
KB-03-01-04	National Nuclear Data Center Reference Nuclear Data for Energy Research	Dunford, C.
KJ-01-01-01	Numerical Algorithms for the Magnetohydrodynamics	Samulyak, R. and others
KJ-01-01-01	The Terascale Simulation Tools and Technologies (TSTT) Center	Glimm, J.
Fueling the Future		
EB-22-01-00	Health and Environmental Effects of Photovoltaic Energy	Fthenakis, V.
KC-02-01-03	Superconducting Materials	Suenaga, M.
KC-02-02-01	Neutron Scattering	Tranquada, J.
KC-02-02-01	X-Ray Scattering	Gibbs, D.
KC-02-02-01	Powder Diffraction	Vogt, L.
KC-02-02-02	Charge Inhomogeneity in Correlated Electron Systems	Gibbs, D.
KC-02-02-02	Electron Spectroscopy	Johnson, P.
KC-02-02-03	Condensed Matter Theory	Weinert, M.
KC-02-03-01	Synthesis and Structures of Conducting Polymers	Mc Breen, J.
KC-03-02-04	Structure and Function in Electrochemistry and Electrocatalysis	Adzic, R.
KC-02-01-01	Studies of Nanoscale Structure and Structural Defects of Advanced Materials	Zhu, Y.
KC-03-01-02	Gas-Phase Molecular Dynamics	Muckerman, J.
KC-03-01-02	Photoinduced Molecular Dynamics in the Gas and Condensed Phases	White, M.
KC-03-02-01	Catalysis: Reactivity and Structure	Hrbek, J.
TA-01-00-00	Global MARKAL Model Development (EIA)	Lee, J.
KC-02-02-02	Structure Sensitive Properties of Advanced Permanent Magnet Materials: Experiment and Theory	Welch, D.
KC-03-01-01	Structure-Function Designs of Photosynthetic and Catalytic Porphyrins	Fajer, J. and Feldberg, S.
KC-03-01-01	Thermal, Photo- and Radiation-Induced Reactions in Condensed Media	Miller, J.
KC-06-00-00	Regulation of Energy Conversion in Photosynthesis	Hind, G.
KC-06-00-00	Modification of Plant Lipids	Shanklin, J.
Protect Our Living Planet		
AA-20-25-20	Mercury Risk Assessment	Moskowitz, P.
EB-27-00-00	Greenhouse Emission Target in Bolivia	Lee, J.
KP-11-01-01B	Analysis of Human Proteins Induced in Response to Ionizing Radiation	Studier, W.
KP-11-02-02	DNA Damage Clusters in Low Level Radiation Responses of Human Cells	Sutherland, B.
KP-11-03-01	Genome Sequencing and Analysis	Dunn, J.
KP-12-01-03	Direct and Indirect Effects of Aerosols: Short-wave Radiative Forcing by Tropospheric Aerosols	Schwartz, S.
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Multi-Phase Atmospheric Chemistry	Lee, Y.
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Field Studies in Atmospheric Chemistry	Daum, P. and Newman, L.
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Diagnostic Model Studies Using Field Observations and Eulerian Model Output	Kleinman, L.
KP-12-02-01	Anthropogenic Aerosol Perturbation on Climate	Schwartz, S.
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Instrumentation for Field Programs	Springston, S.
KP-12-02-01	Perfluorocarbon Tracer Studies for Visualization/Verification of Vertical Transport and Mixing (VTMX) Processes	Dietz, R.
KP-12-02-01	Eddy-Covariance Flux Tower and Tracer Support for the University of Georgia Proposal: "From Tower to Pixel	Hendrey, G.
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Aerosol Size Distribution	Brechtel, F.
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Aerosol Optical Properties and Phase Transformation	Imre, D.
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Chemical and Microphysical Aerosol Model	Schwartz, S.
KP-12-02-02	Forest Atmosphere Carbon Transfer and Stroage-1 (FACTS-1)	Hendrey, G.

MISSION: SCIENCE AND TECHNOLOGY		
B & R	*PROGRAM TITLE*	*PRINCIPAL INVESTIGATOR*
	Experiment in a Forest Ecosystem Off-site	
KP-12-02-02	Observations, Analysis and Modeling of the Water Cycle	Miller, M.
KP-12-03-02	Free-Air Carbon Dioxide Enrichment (FACE) Facility Development	Hendrey, G.
KP-14-01-03	Imaging the Awake Animal	Ernst, T.
KP-14-01-05	Targeted Ablation of Animal Tumors by Boron Neutron-Capture Therapy (BNCT)	Miura, M.
EW-40-90-10	Mechanisms of Radionuclide-Hydroxycarboxylic Acid Interactions for Decontamination of Metallic Surfaces	Francis, A.
KC-03-02-02	Thermodynamics on the Nanoscale	Imre, D.
KP-11-01-01B	Non-Homogeneous End Joining DNA Repair: Characterization of Protein Structures and Complexes	Anderson, C.
KP-13-01-01	Stabilization of Heavy-Metal Contaminants in Subsurface Environments: Microbially Mediated Precipitation of Metal Sulfides from Complexes with Organic Chelates	Vairavamurthy, A.
KP-13-01-01	Reductive Precipitation and Stabilization of Uranium Complexed With Organic Ligands by Anaerobic Bacteria	Francis, A.
KP-14-01-02	Radiotracer Chemistry and Neuroimaging	Fowler, J.
KP-14-01-03	High-Field Magnetic Resonance Imaging	Ernst, T.
KP-14-01-04B	Physiological Imaging	Volkow, N.
KP-14-01-05	Positron Emitter Labeled BPA for BNCT	Ding, Y.
KP-14-01-06	Neuroreceptor Radioligands and Synaptic Activity	Gatley, J.
ST-01-01-02	Radioisotope Production at BLIP	Mausner, L. and Srivastava, S.
KP-12-02-02	In Situ Non-Invasive Soil Carbon Measurement (SCM)	Wielopolski, L.
Manage As Stewards Of The Public Trust - Scientific and Operational Excellence		
CN-04	Counter Intelligence Program Funding	Gross, G.
CN-04-01	Technology Review	Indusi, J.
FS-10-01	Site Safeguards and Security and Cybersecurity	Reaver, R
FS-10-02	Security Systems	Reaver, R.
FS-10-04	Information Security	Reaver, R.
FS-10-05	Cyber Security	Reaver, R.
FS-10-05	ITD Cyber Security- Unclassified	Sadler, C.
FS-10-09	Program Management	Reaver, R.
DP-09-01-19	Safety Management Verification and Operational Readiness	Perkins, K.
DP-09-09-09	RAP Program	
DP-09-09-11	Technical Program Support to Emergency Management Advisory Committee (EMAC) Subcommittee on Consequence Assessment and Protection	Hansen, D.
HC-10-04	BNL Support for DOE Orders, Standards, and Rules	Perkins, K.
HC-10-09-00	Integrated Safety Management Systems Support	Perkins, K.
HD-20-06-20	Brookhaven National Laboratory Health Surveillance System	Sbarra, L.

MISSION: ENERGY RESOURCES		
B & R	*PROGRAM TITLE*	*PRINCIPAL INVESTIGATOR*
Advanced Power Systems		
AF-45-30-00	Human Factors Guidance for Digital Instrumentation and Control (I&C) Systems and Hybrid Control Rooms	O'Hara, J.
EE-05-02-00	Characterization of New Fuel Cell Electrocatalysts	
EE-05-02-00	Low Platinum Loading Catalysts for Fuel Cells	
EB-50-01-00	Practical Conductor Development for Electric Power Systems Utilizing High -Tc Oxides	Suenaga, M.
Efficient and Productive Energy Use		
EE-05-01-00	Lithium-Ion Cell Diagnostics and Evaluation	McBreen, J.
EE-05-05	Battery Materials: Structure and Characterization	McBreen. J.
EC-09-04-00	Thermal Distribution Systems in Small Buildings	Andrews, J.
EO--01-01	Oil Heat Research	McDonald, R.
Reliable and Diverse Energy Supply		
AC-10-05-00	Natural Gas and Oil Technology Partnership	Goland, A.
AC-10-15-00	Characterization and Reaction Behavior of Sterically-Hindered Sulfur Compounds in Heavy Crudes	Devinder, M.
EB-40-01-00	Geothermal Materials Development	Berndt, M.
EB-40-01-00	Advanced Processes for Geothermal Brines Multiple Resources	Lin, M.
EE-06-02-00	Natural Gas Storage Systems	Wegrzyn, J.
EH-01-20-06	Energy Environment Economic Modeling for Strategic Planning, Energy Intensity, Technology Evaluation, Policy Analysis	Lee, J.
EC-09-04-00	Application of Advanced Fuel Preparation Techniques	Butcher, T.

MISSION: ENVIRONMENTAL QUALITY		
B & R	*PROGRAM TITLE*	*PRINCIPAL INVESTIGATOR*
Enhance Future Land Use		
EX-04-C4-02	Decontamination and Decommissioning: BGRR	Hill, L.
EX-08-CC-01-0	Excess Facilities	Hill, L
KP-14-01-05	Brookhaven Medical Research Reactor Project	Hill, L.
EX-04-C4-04	BNL Environmental Restoration and Waste Management - Remedial Actions	Hill, L.
KP-13-01-01	The Microbial Stabilization of Plutonium in the Subsurface Environment	Francis, A.
NN-41-02-00	Nuclear Cities Initiative (Environmental)	Moskowitz, P.
Management of Waste/Materials		
AF-57-00	BNL Support to the Advanced Accelerator Applications Program	Todosow, M.

MISSION: NATIONAL SECURITY		
B & R	*PROGRAM TITLE*	*PRINCIPAL INVESTIGATOR*
Monitoring Nuclear Treaties and Agreements		
NN-40-03-00	International Safeguards	Gordon, D.
Preventing Proliferation		
NN-40-06-02	Nuclear Cities (Environmental)	Moskowitz, P.
FS-10-07	Material Control and Accountability	Reaver, R.
NN-40-01-00	NN 40-01 Russian Subcontracts	Indusi, J.
NN-41-01-00	Initiatives for Proliferation Prevention (IPP)	Rohatgi, U.
NN-50-01-00	Non-Proliferation and National Security	Indusi, J.
NN-50-03-00	National Security and Non-Proliferation	Indusi, J.
NN-50-04-00	National Security and Non-Proliferation	Indusi, J.
Countering Weapons of Mass Destruction Terrorism		
IN-01-06-00	Technical Analysis and Program Support for the Special Technologies Programs	Lemley, J.
NN-41-01-00	Initiatives for Proliferation Prevention (IPP) Support	Rohatgi, U.
NN-50-03-00	Technical Support to the International Nuclear Safety Program	Kohut, P., Ginsberg, T. Azam, M.
NN-20-04-00	Targeted Diagnostics for Biological Non-Proliferation	

Appendix B: User Facility Information

Table B1 - Experimenters At User Facilities

Facility	Number of Experimenters	Number of Organizations
RELATIVISTIC HEAVY ION COLLIDER		
BNL	108	1
Other Federal Labs	365	43
University	606	93
Industry	1	1
International	(485)	(84)
	1080	138
ALTERNATING GRADIENT SYNCHROTRON/TANDEM VAN DE GRAAFF COMPLEX		
BNL	22	2
Other Federal Labs	163	31
University	252	77
Industry	130	46
International	(192)	(63)
	567	156
NATIONAL SYNCHROTRON LIGHT SOURCE		
BNL	250	1
Other Federal Labs	201	31
University	1379	162
Industry	161	63
International	244	115
Other	178	44
	2413	416
SCANNING TRANSMISSION ELECTRON MICROSCOPE		
BNL	8	1
University	52	39
Other Federal Labs	10	2
Other	0	0
	70	42
ACCELERATOR TEST FACILITY		
BNL	9	1
Other Federal Labs	7	4
University	19	10
Industry	1	1
International	(11)	(5)
	36	16

Table B2 - Industrial and Technological Users of the National Synchrotron Light Source

Abbott Bioresearch Center	Abbott Laboratories
Advanced Control Systems	ALIAS Aerospace, Inc.
AlliedSignal, Inc.	Area Detector Systems Corporation
Aventis Pharma	Bechtel Nevada
Biogen Incorporated	Biological Research Center
BioSpace International Inc.	BIOTEC, NSTDA
Biotechnology Research Institute	Boehringer Ingelheim Pharmaceuticals Inc.
Boeing Company	BP Amoco
Bristol-Myers Squibb	Bruker AXS, Inc.
Bruker Optics Inc.	Celera
Chevron Research & Technology Company	Chiron Corporation
Crystal Logic Incorporated	Dow Chemical Company
DuPont Merck Pharmaceuticals	Edge Analytical, Inc.
Emerald BioStructures, Inc.	Evans East
ExxonMobil Research and Engineering Co.	Geltex Pharmarceuticals, Inc.
General Electric	GlaxoSmithKline
GTE Labs	Hoffmann-La Roche
Honeywell International	IBM Research Division
KLA Instruments	Lucent Technologies, Inc.
Merck & Co.	Microcoating Technologies
Montell Polyolefins USA	Nanoprobes
Natural Resources Canada	New Century Pharmaceuticals, Inc.
Nicolet Instrument Corporation	Osram Sylvania, Inc.
Oxford Cryosystems Inc	Oxford Diffraction
Panametrics, Inc.	Pfizer, Inc.
Philip Morris USA	Princeton Gamma-Tech
Radiation Monitoring Devices, Inc.	Rib-X Pharmaceuticals, Inc
Rigaku/MSC, Inc.	Rohm & Haas Co.
Schlumberger-Doll	Science Applications International Corp.
Sci-Med	SensIR Technologies
SFA, Inc.	Southern Research Institute
SRS Technologies	SSCI, Inc
Suntory Pharmaceutical Research Laboratories	UOP
Westinghouse Savannah River Co.	Wyeth-Ayerst Research
X-ray Optical Systems, Inc.	

Table B3 - Users of the Relativistic Heavy Ion Collider

Abilene Christian University	Academia Sinica
Ames Laboratory	Argonne National Laboratory
Banaras Hindu University	Bhabha Atomic Research Center (BARC)
Brookhaven National Laboratory	Carnegie Mellon University
Centre National de La Recherche Scientifique (CNRS)	CERN
CETECOM GMBH	China Institute of Atomic Energy (CIAE)
City University of New York (CUNY)	Columbia University
Columbia University, Nevis Laboratories	Commissariat A l'Energie Atomique (CEA)
Creighton University	Cyclotron Application Laboratory
Debrecen Universitas	Detroit Board of Education
Ecole Polytechnique	Eotvos Lorand University
Florida Institute of Technology	Florida State University
Georgia State University	Gesellschaft für Schwerionenforschung-GSI
Hiroshima University	Hope College
Huazhong Normal University	Hungarian Academy of Sciences – RIPNP
Indiana University @ Bloomington	INFN - Laboratori Nazionali di Frascati
Institut de Recherches Subatomiques, Strasbourg (IReS)	Institut Fuer Kernphysik
Institute de Physique Nucleaire	Institute for High Energy Physics (IHEP), Russia
Institute for Theory & Experimental Physics (ITEP)	Institute of High Energy Physics (IHEP), Beijing
Institute of Nuclear Physics (Poland)	Institute of Particle Physics
Institute of Physical and Chemical Research	Institute of Physics (Czechoslovakia)
Institute of Physics (India)	Institute of Space Sciences
Instituto Nazionale di Fisica Nucleare (INFN)	Iowa State University
Jagellonian University	Japan Society for the Promotion of Science
Johns Hopkins University	Joint Institute for Nuclear Research (JINR)
Kangnung National University	KEK-High Energy Accelerator Research Org
Kent State University	KFKI Atomic Energy Research Institute
Korea University	Kyoto University
Laboratory of High Energy	Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory	Los Alamos National Laboratory
Lund University	Massachusetts Institute of Technology
Max Planck Institute	Michigan State University
Moscow Inst of Radiotech.Elect. & Automat. (MIREA)	Moscow State Engineer. Physics Inst (MEPhI)
Myongji University	Nagasaki Institute of Applied Science
NASA - Goddard Space Flight Center	National Central University
National Inst for Nuclear Physics and High Energy Phys	New Mexico State University
New York University	Niels Bohr Institute
Notre Dame University	Nuclear Physics Institute of the ASCR
Oak Ridge National Laboratory	Ohio State University
Pennsylvania State University	Petersburg Nuclear Physics Institute (PNPI)
Purdue University	Res Inst for Tech Physics & Materials Science
Rice University	RIKEN
RIKEN Brookhaven Research Center	Rikkyo University
Russian Research Center - Kurchatov Institute	Russian Scientific
Seoul National University	Subatech
SUNY @ Stony Brook	Texas A&M University
Texas Technical University	Tokyo Institute of Technology (TIT)
Tsukuba College of Technology	Universite Blaise Pascal
Universite de Clermont-Ferrand	University of Arkansas
University of Bergen	University of Bern
University of Birmingham	University of Bucharest
University of California @ Berkeley	University of California @ Davis

Brookhaven National Laboratory

University of California @ Los Angeles University of Catania University of Colorado University of Frankfurt University of Illinois University of Illinois @ Urbana-Champaign University of Kansas University of Maryland University of New Mexico University of Peking University of Sao Paulo University of Tennessee University of Texas @ Austin University of Trieste University of Washington Variable Energy Cyclotron Center Warsaw University Waseda University Weizmann Institute of Science Yale University York College - The City University of New York (CUNY)	University of California @ Riverside University of Chicago University of Copenhagen University of Heidelberg University of Illinois @ Chicago University of Jammu University of Louis Pasteur University of Münster University of Oslo University of Rochester University of Science & Technology of China University of Texas @ Arlington University of Tokyo University of Tsukuba Vanderbilt University Wake Forest University Warsaw University of Technology Wayne State University Western Michigan University Yonsei University

Table B4 –Users of the Alternating Gradient Synchrotron	
Abilene Christian University	Alabama A&M University
Argonne National Laboratory	Arizona State University
Bechtel Nevada	Brookhaven National Laboratory
Boston University	Budker Institute of Nuclear Physics
Carnegie Mellon University	Case Western Reserve University
CERN	Cleveland Clinic Foundation
College of William & Mary	Colorado State University
Columbia University	Columbia University, Nevis Laboratories
Consiglio Nazionale delle Ricerche	Darmstadt University of Technology
Fairfield University	Fermi National Accelerator Laboratory
Forschungszentrum Juelich (KFA)	Fukui University
George Washington University	Gifu University
Hampton University	Idaho State University
Illinois Institute of Technology	INFN - Laboratori Nazionali di Frascati
Institut Fuer Kernphysik	Institute for High Energy Physics (IHEP), Russia
Institute of Nuclear Physics	Instituto Nazionale di Fisica Nucleare (INFN)
Japan Atomic Energy Research Institute (JAERI)	Johns Hopkins University
KEK - High Energy Accelerator Research Org.	Kent State University
Kyoto University	Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory	Loma Linda University
Loma Linda University Medical Center	Los Alamos National Laboratory
Massachusetts General Hospital	Max Planck Institute
Montana State University	Morehead State University
NASA – Columbia University	NASA - Goddard Space Flight Center
NASA - Johns Hopkins Hospital	NASA - Johnson Space Center
NASA - Loma Linda University Medical School	NASA - New York University School of Medicine
National Aeronautics and Space Admin. (NASA)	National Defense Academy of Japan (NDAJ)
New York University	Northwestern University
Oak Ridge National Laboratory	Osaka University
Paul Scherrer Institute	Petersburg Nuclear Physics Institute (PNPI)
Prairie View A&M University	Princeton University
Rensselaer Polytechnic Institute	Rudjer Boskovic Institute
SRI International	St. John's University
SUNY @ Stony Brook	Tel Aviv University
Texas A&M University	Inst for Nuclear Res of the Russian Acad.of Sciences
Thomas Jefferson National Accelerator Facility	Tohoku University
Tokyo Institute of Technology (TIT)	TRIUMF
U.S. Department of Agriculture	Uniplast
Universita di Napoli	Universities Space Research Association
University of Alberta	University of British Columbia
University of California @ Irvine	University of California @ Los Angeles
University of California @ Riverside	University of California @ San Francisco
University of Colorado	University of Delhi
University of Freiburg	University of Genova
University of Groningen	University of Heidelberg
University of Houston	University of Illinois
University of Illinois @ Urbana-Champaign	University of L'Aquila
University of Maryland	University of Massachusetts

University of Milano	University of Minnesota
University of New Mexico	University of Notre Dame
University of Pennsylvania	University of Perugia
University of Pittsburgh	University of Puerto Rico
University of Regina	University of Rome II
University of Tokyo	University of Washington
University of Zagreb	University of Zurich
Uppsala University	USDA - Human Nutrition Research Center on Aging
Valparaiso University	Wyle Laboratories @ Houston
Yale University	

Appendix C: Work For Others

National Aeronautics and Space Administration (NASA): The AGS currently is accelerating Fe ions to energies up to 1.0 GeV per nucleon in a radiobiology program for NASA's Space Radiation Health and Radiation Biology Division. This work will expand a very limited experimental database on long missions into interplanetary space by humans. This program runs several times per year, with heavy-ion irradiations for 20-30 experiments annually. The users are approved and funded by NASA, which purchases the AGS time.

National Institutes of Health (Department of Health and Human Services): Several of BNL's centers and facilities are developed and operated through partnerships with, and funding from, the National Institutes of Health. Such partnerships include the development of facilities for synchrotron crystallography at the NSLS as well as support to our Center for Imaging and Neuroscience and the Scanning Transmission Electron Microscope. NIH also provides substantial support through research grants to individual investigators in the fields of molecular biology and brain imaging.

Environmental Protection Agency (EPA): New York Harbor is faced with an operational crisis in removing sediments and soils contaminated with a variety of anthropogenic toxic materials. BNL is collaborating with the U.S. Army Corps of Engineers to produce dredged material treatment technologies that are environmentally effective and economically affordable.

International cooperation is critical to achieving EPA's mission. The EPA Office of International Activities (OIA) enlists the cooperation of other nations in solving environmental problems of concern to the U.S. BNL staff assists this office in designing and overseeing the construction of a waste processing facility in Murmansk, Russia. We provide technical support in evaluating Russian technologies for waste treatment and, through the OIA, are fostering environmentally sound, sustainable development initiatives in Kazakstan.

Department of Defense (DOD): We developed and demonstrated a novel high-performance oil-fired thermo-photovoltaic system for generating electric power under field conditions with DARPA funding. The design is being improved to increase conversion efficiency.

Several key activities are underway to develop coatings and materials that will be better able to resist corrosion. In addition, we are supporting the U.S. Army in the Chemical and Biological Defense Command (CBDCOM) by assessing the fluorescence properties of humidified and coated biological particles.

US Nuclear Regulatory Commission (NRC): BNL provides technical support to the NRC and performs safety related research for them. This work includes risk assessment, reliability analysis, thermal-hydraulic and neutronic-analyses evaluations related to life extension and licensing renewal, analyses of external events, human system interface research, structural-, mechanical- and earthquake-engineering analysis, operational safety assessments, and reviews of plant-specific safety issues.

BNL constructed and operates the High-Temperature Combustion Facility (HTCF), a unique facility for investigating high-temperature, high-speed combustion phenomena (including detonations). The Laboratory provides environmental qualification information on aged electrical cables using experimental condition-monitoring resources housed in our Electric Cable Test Facility. BNL is heavily involved in technology transfer and training of regulatory staff in the U.S. and in countries of the former Soviet Union. We also collaborate in seismic research with NUPEC of Japan.

Brookhaven National Laboratory

Department of State (DOS): The Department of State funds Brookhaven's International Safeguards Project Office (ISPO), which supports the IAEA in nuclear safeguards. The ISPO provides ongoing technical review and management of the U.S. Program of Technical Assistance to IAEA Standards (POTAS), as well as advice on new initiatives to enhance the effectiveness and efficiency of IAEA safeguards. Currently, ISPO tracks nearly 100 active projects. Additional funds may be secured for initiatives focusing on managing Russian radioactive waste.

We continue to offer technical support and conduct programs related to simulators, provide training to enhance the safe operation of nuclear power plants, decommissioning and decontamination, and waste management, and use our capabilities to support work in Eastern Europe and the nations of the former Soviet Union.

Federal Aviation Administration (FAA): BNL is performing risk- and reliability-analyses and assessments of threats by insiders and outsiders to assist the FAA in ensuring aircraft system reliability, availability, maintainability, and in airport security. This work includes using probabilistic-risk analysis techniques, developed and proven for applications to nuclear power plants, to glean risk-related insights from recent incidents and accidents in commercial aircraft, and for improving the reliability of specific aircraft components.

Non-Federal Sponsors: BNL has over fifty projects for non-federal sponsors in the U.S. and other countries. These projects support research primarily in the areas of energy technologies, environmental sciences, materials sciences, and biomedical research and development. About 30 are for private entities, 15 for academic institutions, and the others for state/local governments and organizations in other countries. This work is one of the ways that BNL supports the DOE's missions in developing advanced technologies that address national needs, and in disseminating technical knowledge and maintaining technical capabilities in the nation's workforce.

Other DOE Contractors: BNL conducts over 40 projects to support work with other DOE contractors. This work provides BNL's unique capabilities to support the DOE's missions by working with other DOE Contractors. Our largest endeavor involves the Spallation Neutron Source Collaboration.

	Table C1 - FY 02 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
	DEPARTMENT OF COMMERCE	
NOAA	Aerosol Measurements at Cheju Island	EENS
	Compilation & Analysis of Emissions Inventories for the N.A. Regional Experiment	EENS
	G-1 Measurements for Summer 2002 New England Air Quality Study	EENS
	Support for the National Weather Service	EP
NIST	NIST Research Reactor Control Room Upgrade Plan	EENS
	DEPARTMENT OF DEFENSE	
ARMY	Comparing X-Ray Microbeams & Broad Beams at Optimal Configurations in a Model of Metastatic Breast Cancer	BO
	Structural Studies on Intact Clostridium botulinum Neurotoxin Complexed with Inhibitors Leading to Drug Design	BO
	A field Program to Identify TRI Chemicals and Determine Emission Factors	EENS
	Amorphous Pre-ceramic and Crystalline Organic Polymers for High Performance Coatings, Adhesives, and Composites	EENS
	Design, Development & Fabrication of a Breadboard Prototype 500W TPV Power Source Phase I	EENS
	Fluorescence Yields on Humidified & Coated Aerosol Particles	EENS
	FY99 Domestic Preparedness Program	HP
	Non-destructive Evaluation of Corrosion Under Coatings	MA
	Imaging Illicit Drug Abuse: Development of a New Test-Bed Using MRI Microscopy and Molecular Modeling	MO
DARPA	Development of a Compact Source for Dual-Energy Digital Subtraction Angiography	NSLS
DNA	ETA Fission Track Analysis	EENS
NAVY	Arctic Military Environmental Cooperation	EENS
	Remediation, Removal & Replacement of Storage Tank at National Naval Medical Center	EENS
ONR	Shipboard Acoustic Doppler Profiles in the Arabian Sea	EENS
	Morphology Study of UDF CoPolymer & Terpolymer Relaxors by Simultaneous Time Resolved SAXS/WAXS	NSLS
	Gain Harmonic Generation Experiments at the Source Development Laboratory of NSLS	NSLS
	DEPARTMENT OF HEALTH AND HUMAN SERVICES (DHHS) - PROGRAM 40	
NIAAA	Dopaminergic Brain Function in Alcoholics	MO
NIDA	Operating Funds for Regional NIDA Neuroimaging Center	MO
	PET in Cocaine Abuse	MO
	PET Studies of Brain Dopamine in Cocaine Abusers	MO
	Pharmacokinetics of Psychostimulants & Reinforcement	MO
NIGM	Nondiamagnetic Agents in In-Vivo 23NA & 1H20 MR	CO

	Table C1 - FY 02 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
NIH	Adenovirus Protease Regulation and Antiviral Development	BO
	Adenovirus Receptor Interaction Structure Function	BO
	Development for Macromolecular Crystallography at the NSLS	BO
	DNA Damage Clusters: Repair in Mammalian Cells	BO
	DNA Damage Quantitation by Single Molecule Laser Sizing	BO
	DNA Mismatch Repair and Mutation Avoidance	BO
	Genetic Variation in Human NHEJ DNA Repair Genes	BO
	Modulation of Neutrons Matter Release by Cannabinoids	BO
	STEM Mass Mapping & Heavy Atom Labeling of Biomolecules	BO
	Structure- Function Relationships in Glutaminase A	BO
	Structures of Botulinum Toxin and Rational Drug Design	BO
	The Structural Basis of Selective Permeability in Aquaporins	BO
	Vaccine Intervention for Lyme Borreliosis	BO
	4 Tesla MRI Bolus CR Studies of Human Brain BBB Permeability	CO
	Optimizing Intensity and Duration of GVG Pharmacotherapy	CO
	PET Investigations of Abused Inhalants	CO
	Acoustic Interference on Attention in HIV Patients	MO
	Activation Studies in Early HIV Dementia	MO
	Behavioral Correlates of FMRI Response in Cocaine Users	MO
	Brain Dopamine Function in Adults with ADHD	MO
	Brain Dopamine Pathology in Obese Individuals	MO
	Brain Imaging and Drug Abuse	MO
	Ceramid and Radiation Induced Apoptosis in CNS Glia	MO
	Doperamergic Brain Function in Alcoholics	MO
	Estimation of Synaptic Dopamine using PET & SPECT	MO
	Feto-Maternal Pharmacokinetics of abused Inhalants	MO
	Human Brain Pharmacokinetics of (-) Delta 9 Thc	MO
	Magnetic Resonance Spectroscopy to Monitor HAART in HIV Brain Injury	MO
	Microbeam Radiation Therapy for Gliomas	MO
	Monitoring Methamphetamine Abuse Treatment with 1H MRS	MO
	Monoamine Oxidase Inhibition and Nicotine Reward	MO
	PET Studies of Brain Dopamine in Stimulant Abusers	MO
	Radiotracer R&D in Nuclear Medicine and Neurosciences	MO
	CLP: An Archetypal ATP-Dependent Protease	NSLS
	Metals & Protein Structure in Protein Folding Diseases	NSLS

FUNDING AGENCY	Table C1 - FY 02 Work For Others by Project TITLE	DEPARTMENT
	X6A Protein Crystallography Beamline	NSLS
	DEPARTMENT OF STATE	
AID	BNL Advisors to the Intentional Science and Technology Center	EENS
	International Safeguards Project Office POTAS	EENS
	MARKAL Workshop at BNL	EENS
	ENVIRONMENTAL PROTECTION AGENCY	
EPA	Develop Markal Macro for the State of New Jersey	EENS
	Development a Decision Support Technology Matrix and Reference Guide	EENS
	Development of the MARKAL-MACRO Model for Puerto Rico	EENS
	Facility for Liquid Radioactive Waste Associated with the Decommissioning of Russian Nuclear Submarines	EENS
	Geochemical Analysis of Sediment from the Kara Seas	EENS
	Goal Programming for the Harmonization of Environmental Programs	EENS
	MARKAL MACRO Development in Central America	EENS
	NY/NJ Harbor Sediment Decontamination Tech. Demonstration: Phase II Pilot Scale	EENS
	Southern Oxidants Study Research Program at BNL	EENS
	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	
NASA	Biological Beam Experiments	BO
	Germ Cell Mutagenesis in Medaka Fish Following Exposure to Heavy, High Energy Cosmic Ray Nuclei	BO
	Booster Applications Facility	CA
	Genetic and Epigenetic Effects Produced by High Energy Heavy Ions	CA
	An Advanced Gamma-Ray Spectrometer for Determining Geological Activity & Composition of Planetary Bodies	DA
	Reaction Pathways & Thermodynamic Studies of Atmospheric Reactions	EENS
	Representation of Aerosol Microphysics in Regional to Global Scale Models	EENS
	Validation of the SeaWiFs Atmospheric Correction Scheme using Measurement of Aerosol Optical Properties	EENS
	Provide Support for Animal & Cell Biological Experiments	MO
	NUCLEAR REGULATORY COMMISSION (NRC)	
NRC	Advanced Reactor Regulatory Framework Development	EENS
	Armenian Nuclear Regulatory Authority-Development of a Safety Analysis Review Capability	EENS
	Armenian Nuclear Regulatory Authority-Development of a Safety Analysis Review Capability	EENS
	Boiling Water Reactor Fluence	EENS

	Table C1 - FY 02 Work For Others by Project	
FUNDING AGENCY	TITLE	DEPARTMENT
	Collaborative Research on Wire System Aging	EENS
	Credit for Operator Action	EENS
	Digital Systems PRA	EENS
	Dry Cask PRA	EENS
	EQ/Aging Power Cables and Electrical Penetration	EENS
	Estimate for Construction of PPS Drop Test Facility	EENS
	Improved Methods for Performing Importance Analysis	EENS
	Japanese Collaboration on Seismic Issues	EENS
	Low Power and Shutdown Risk Study-Level 2	EENS
	Nuclear Safety Research Information Meeting	EENS
	Radiological Emergency On-Shift and Augmentation Staffing Levels for Nuclear Power Plants	EENS
	Reactor Analysis for High-Burnup Fuel	EENS
	Reactor Core Analysis	EENS
	Risk Associated with Cable Aging	EENS
	Risk Informed Initiatives for Nuclear Materials	EENS
	Risk-Informing Part 50	EENS
	Role of Human Performance in Advanced Reactors	EENS
	Seismic Response of Degraded Structures and Components	EENS
	Soil-Structure Interaction for Buried Structures	EENS
	SPAR Model Development Level 2/LERF	EENS
	Strengthening Kazak Regulatory Authority	EENS
	Strengthening Kazak Regulatory Authority	EENS
	Support for Inspection and Assessment Program Development and Oversight	EENS
	Support in Development of Consensus PRA	EENS
	Support to Russian Federal Nuclear and Radiation Safety Authority	EENS
	Support to State Nuclear Regulatory Committee of Ukraine	EENS
	Support to State Nuclear Regulatory Committee of Ukraine	EENS
	Support to State Nuclear Regulatory Committee of Ukraine	EENS
	Task 4: Rev. of Nuclear Energy Institute Industry Initiative	EENS
	Task 8: Review of the VCSNS License Renewal Application in Areas Relating to the Contaminants, Structures and Component Support	EENS
	Technical Assistance for Risk Assessment of Nuclear Materials and Waste	EENS
	Technical Assistance in Support of DSSA Reactor System Issues	EENS
	Technical Assistance in Support of DSSA Regulatory Licensing Improvements	EENS

FUNDING AGENCY	Table C1 - FY 02 Work For Others by Project TITLE	DEPARTMENT
	Technical Assistance in Support of Technical Evaluation of Non-Power Reactors-University of Maryland License Renewal	EENS
	Technical Assistance in Support of the Division of Engineering Review of Inservice Inspection Relief Request Licensing Actions	EENS
	Technical Assistance in Support of the Division of Engineering Regulatory Licensing Improvement Activities	EENS
	Technical Assistance in Support of the Division of Engineering Review of Design Certification Applications	EENS
	Technical Support for the Russian Kalininskaya	EENS
	Technical Support in Risk Assessment	EENS
	NATIONAL SCIENCE FOUNDATION PROGRAM 40	
NSF	Charged Species in Supercritical Fluids	CO
	OTHER FEDERAL AGENCIES - PROGRAM 40	
DOE NN-30	Safeguards Analysis	EENS
DOI/NPS	Tracer Study of Long Range Transport in Support of BRAVO	EENS
DOT/FAA	Development of a Variable Frequency Approach for Monitoring Condition of Aircraft Wiring	EENS
DOT/FAA	Applying Probabilistic Safety Assessment to Aircraft Safety	EENS
FAA	Applying Probabilistic Risk Assessment Methodology to Aircraft Safety	EENS
PETC	Clean Coal Fossil Fuels and Energy Efficiency	EENS
	PRIVATE ENTITIES	
Aerodyne Research, Inc Texas	Development of a Versatile Aerosol Mass Spectrometer for Organic Aerosol Analysis	EENS
Airborne Contaminant Systems, Inc.	Testing of Filtration Efficiency on Device for Removal of Biological/Radiological Hazards Injected into Commercial Air Handling Systems	EENS
Allergen, Inc.	Crystallization of Botulinum Neurotoxin Type E Light Chain	BO
Battelle Memorial Institute	Technical Support for BMI Technology Platforms	TT
Brookhaven Science Associates	BSA Corporate Grant Sharing Account	DO
Columbia Univ.	Influences of Atmospheric Aerosol on Precipitation in the Tropics	EENS
Cooley's Anemia Foundation	A Novel Method to Measure Iron In Vivo in the liver and Heart of Thalassemia Patients	EENS
Cornell Univ.	CADD-Based Expert System for Passive Snow Removal	EENS
Cornell Univ.	Tort Law Database	EENS
Cotton, Inc.	Genes Controlling Cotton Fiber Properties	BO

	Table C1 - FY 02 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
Eli Lilly & Co.	Effects of Tomoxetine and Phentermine on [11C]	MO
Emory University	AIDS and Opiates: A Monkey Model	MO
ENCONET	Risk Informed Applications for Nuclear Power Plants	EENS
Energy Research Center, Inc.	New York State Premium Low-Sulfur Fuel Marketplace Demonstration	EENS
EPRI	Development of Technical Bases for Guidance for Digital Control Room Technologies	EENS
Georgia Inst. Technology	Measurement of Particle Chemical Composition During NASA TRACE-P	EENS
Houston Advance Research Center	Quantification of Fugitive Reactive Alkene Emissions from Petrochemical Plants with Perfluorocarbon Tracers	EENS
Insight Technologies, Inc.	BNL Technical Support on the Development of a Two-Stage Oil Burner with Load-Tracking Control	EENS
ITT Industries	Ultraviolet Raman Spectral Signature Acquisition and Short-Range Raman Lidar Optical Physics	EENS
KeySpan Energy Corporation	Alternative Repair Materials for Restoring Damaged 16 year-old Insulating Polymer Concrete Dike Overlay	EENS
KeySpan Energy Corporation	Polymer Grouts and Polymer Composite Liners for Retaining Excavated Wall Foundations	EENS
KeySpan Energy Corporation	Recycled Waste-based Cement Composite Materials for Rapid/Permanent Road Restoration and Grout for Soil Stabilization	EENS
Multiple Sclerosis Society	Quantitation of Blood Brain Barrier Permeability in MS Lesion Development	CO
NAARDS	Functional Imaging of Neural Responses to Monetary Reward in Drug Addiction	MO
National OilheatResearch Alliance	Maximizing Fuel Performance in Residential Heating System	EENS
NATO	Assistance for Relational Databases for Nuclear Data	EENS
NATO	The Structure and Risk Assessments of Nuclear Power Plants	EENS
New England Medical Center (NIH)	Selegiline Oxidative Stress & HIV Dementia	MO
New York University School of Medicine	Clinical Correlates of Longitudinal PET Changes in Alzheimer’s Disease	CO
NOCO Energy Corp.	Low Cost Bioheating Oil Applications	EENS
NSBRI	Effect of Deep Space Radiation of Human Hematopoietic Stem Cells	BO
NSBRI	Heavy Ion Microbeam & Micron Resolution Detector	IO
NSBRI	CNS Damage & Countermeasures	MO
NSBRI	Risk Assessment & Chemoprevention of HZE Induced CNS Damage	MO
Penn State University	Development of Cloud Property Retrieval Algorithms at Boundary Facilities	EENS
Polytechnic Univ.	Stormwater Management Practices Study	EENS
Raytheon	Technical Support for the FAA Aircraft Wire Degradation Study	EENS

	Table C1 - FY 02 Work For Others by Project	
FUNDING AGENCY	TITLE	DEPARTMENT
ScrippsResearch Institute (NIH)	Methamphetamine and AIDS Toxic Interactions in Animals	MO
St. Luke's (NIH)	Medical Applications of High Precision Neutron Activation	MO
Structural Genomix, Inc.	Center for Structural Genomics	BO
SUNY-SB	Development of a Transgenic Fish Model for Use in Assessing Genotoxins in the Environment	BO
SUNY-SB	New Approaches for Assessing Mutagenic Risk of Contaminants in the Long Island Sound	BO
SUNY-SB	Regulation of Tissue Repair	BO
SUNY-SB	FMRI of Hormonal Variation in Cognitive-Affective Processing	CO
SUNY-SB	Multi-Objective Optimal Design in Dose Response Studies	CO
SUNY-SB	A Study of the Outer Shelf, Shelfbreak, Front and Slope from Long-term ADCP and Hydrographic Observations from the MV Oleander	EENS
SUNY-SB	PM2.5 Technology and Characterization Study in NY	EENS
Swedish Nuclear Power Inspectorate	Assistance in Nuclear Power Plant Control Room Modernization	EENS
Union Fenosa Group (Spain)	Review of CNJC Design Documentation for Proposed Control Room Modifications	EENS
Univ. California at Irvine	Conceptual Design of the MECO Vacuum Window	PO
Univ. California at San Diego	The Collection of Shipboard Acoustic Doppler Current Profiler Data During the Shelf Basin Interaction Program	EENS
Univ. California at San Diego	Attentional Modulation in Early Sensory Processing	MO
Univ. Colorado	Single-Molecule Field-Effect Transistors	CO
Univ. Connecticut	Project 2: PET & SPEC Radiotracers of Brain Cannabinoid System	MO
Univ. Delaware	The Impact of Surface Precipitation on Sequestration and Bioavailability of Metals in Soils	BO
Univ. Florida	Catalytic Mechanism of Human Mn Superoxide Dismutase	CO
Univ. Penn	Pre-conceptual Design of a Rapid Cycling Medical Synchrotron	CA
Univ. Rochester	US ATLAS Barrel Cryostat Design and Procurement	PO
Univ. Southern Calif.	Attentional Modulation in Early Sensory Processing	MO
Univ. Tokyo	Japan Cooperative Program on Neutron Scattering	PO
Woods Hole (NSF)	Development of Perfluorocarbons as Ocean Tracers	EENS
Woods Hole (NSF)	GLOBEC 01: The Physical Oceanography of Georges Bank and its Impact on Biology	EENS
Yale University	Rice Functional Genomics: Mapping a Male Sterile Gene	BO
Yale University	KOPIO	CA
	STATE AGENCIES & LOCAL GOVERNMENTS	
NYSERDA	Improved Electric Power Efficiency in Heating Equipment	EENS

	Table C1 - FY 02 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
NYSERDA	The Use of Biodiesel Fuel Blends in Space Heating Equipment	EENS
NYSERDA	High Efficiency, Condensing Heating Appliance Firing Low Sulfur Oil	EENS
NYSERDA	Variable Firing Rate Oil Burner Using Pulsed Fuel Flow Control	EENS
Texas Natural Resources Conservation Commission	Analysis of TexAWS 2000 Data	EENS
	OTHER DOE CONTRACTORS	CA
Albuquerque Office	Proton Radiography Experiment	AGS
	FY2000 Joint DOE Integrated Technology Implementation Plan	EENS
	Support U.S. Efforts Directed Toward Current and Potential Arms Control and Nonproliferations Agreements	EENS
Argonne	Criticality and Security of Spent Removable Blocks from Heavy Liquid Metal Cooled Reactors at Sosnovny Bohr, Russia	EENS
	Support the Decommissioning Planning Meeting held at Argonne National Laboratory East	EENS
	Atmospheric Radiation Measurement Program	IO
	SNS Neutron Detectors-BNL Refurbishment	IO
	CSP Nanocomposite Magnets Annual Workshop	MA
Battelle-PNNL	Provide Support to PNNL in assisting INEEI SBMS Development	DH
	Aircraft Measurements PNL 2001 Field Experiment	EENS
	Participation and Scientific Management of ARM Program	EENS
	Various Battelle - PNL Work Orders for Continuation of LISBON Project	EENS
	Dismantling, Packing and Transport Services from BNL for Use of Battelle	EP
	Electroactive Materials for Anion Separation-Technetium from Nitrate	MA
	Foreign Visits and Assignments Database	SE
Chicago Ops. Office	EPA/DOE Environment Management System Audit Review	SE
EML	Optimization of Heterogeneous Use of Th in PWRs to Enhance Proliferation Resistance	EENS
	Samples Project Support	ER
FERMI	Design, Construction and Installation of the Forward Pre-shower Detector for the D Zero Upgrade Project	PHY
Idaho Operations Office	Amorphous Silica	EENS
	Develop Generation IV Technology Roadmap	EENS
	Silica Precipitation by Thermophilic Bacteria in Hot Springs	EENS
LANL	Planning & Design of Superconducting Quadrupoles for the Advanced Hydrotest Facility Lenses	CA
	HMS Modeling Code	EENS
	Design and Produce Twelve Silicon Pixel Detectors	IO
LLNL	Nuclear Closed Cities Initiative	AGS

	Table C1 - FY 02 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
	Engineer & Construct Beamline Stands for the Calorimeter Detector at BNL for Data Taking in the PHENIX Experiment	PO
M2AL68120	Current & Potential Arms Control/Warhead Dismantlement & Nonproliferation Transparency Regimes in Support of DTRA	EENS
NERI	Particle Bed Gas-Cooled Fast Reactor Design	EENS
ORNL	Spallation Neutron Project	AGS
	Provide Support to ORNL Office of Independent Oversight	DH
	Assistant to the ORNL SNS Project	EENS
	Mercury Waste Profiling	EENS
PPP Lab.	National Spherical Torus Experiment NSTX Specification for 2D Position-Sensitive X-Ray Detector	IO
Richland Ops. Office	Generation IV Nuclear Energy Systems	EENS
Rocky Flats Ops. Office	Biomobility of Actinides	EENS
Sandia	SEU Testing	AGS
	Dedicated Beamline for Accelerating Heavy Ions	CA
	Provide Collection & Analysis of Material Control and Accounting Information Special Nuclear Materials	EENS
	Provide V-Copy System Descriptions, System Operations, and Location-Related Documentation for NUREG/CR-6144 Plant	EENS
	Source-Term Calculations for WIPP Performance Assessment	EENS
	Dynamics of Dislocations Near Interfaces in Thin Metal Films	PHY
	Assessment Review Team Services at Sandia National Labs.	QA
Savannah River	PUREX Alternative Treatment Review	EENS
UT-Battelle ORNL	Project Assistance for Deploying SBMS at the DOE Oak Ridge Ops.	DO

Table C2 – CRADA Projects

SPONSOR	TITLE	DEPARTMENT
eV Prod. Div. of II-VI, Inc.	Precision Pulse Processing Circuits for Spectroscopic Imaging	IO
Acceleron	Non-Vacuum Electron Beam Welding	AD
Advanced Energy Systems	Development of High Average Current, High Brightness, All Niobium, Superconducting RF Injector	IO
Aerodyne Research Inc.	On-line Real-Time Characterizations of Nanoparticles Size and Composition	EENS
Applicable Electronics	Non-Invasive Techniques to Study Local Passivity Breakdown of Metal Alloys in Aqueous Media	MA
Brookhaven Technology Group, Inc.	Development of a High Current, High Gradient, Laser Excited, Pulsed Powered Electron Gun	IO
Burle Industries	Project to Develop a Red Side Window Photomultiplier Tube and a Mesh Dynode Proximity Focusing Photomultiplier Tube	PO
Canberra-Aquila, Inc.	Development of Remote Detectors of Breath Alcohol in Moving Vehicles	EENS
Chevron	Catalytic Coprocessing of CO and CO2 Into Methanol Via the BNL Low Temperature Methanol (BNL-LTM) Process	EENS
CTI, Inc.	Non-Invasive Blood Radioactivity Monitor for Quantitative PET Imaging Studies	CO
Curtis Wright	Alternative Welding Process Development	EENS
Dow Chemical Co.	Directed Genetic Engineering of Lipid Metabolism in Plants	BO
DuPont/Kurchatov Institute	Combustion Code for the Chemical Industry	EENS
Excom, Inc.	Development of Application of Pattern Recognition System	EENS
Excom, Inc.	Development of a Multi-Facet Pattern Recognition System	EENS
Fenix Technology	UPEC Heavy Metals Technology Development and Validation	EENS

Table C2 – CRADA Projects

SPONSOR	TITLE	DEPARTMENT
Glaxo Smith Kline	Characterization of Dopamine Transporter Blockade by GW353162 in Human Brain	MO
Glaztec	Use of Chitosan as Waterbased Anticorrosive Coating Material	EENS
GTI	Design and Manufacture of a Prototype Rapid Concrete Cutter Device for Opening of Concrete Pavements above Subterranean Gas Pipelines	EENS
Heat Wise Inc.	Low Nox Commercial Burner	EENS
Honeywell Consumer Products Group	Inhibition of Magnesium Corrosion for Automobile Coolant Application	MA
International Resources Group Ltd.	Energy, Environment and Economic Modeling and Policy Analysis	EENS
Johnson & Johnson	Radiotracer Synthesis and PET Imaging Evaluations for Brain Histamine Receptors	CO
Miravant Medical Technologies	Synchrotron-Based Structural Studies of Hydroporphyrin Sensitizers for Photodynamic Therapy	MA
MIT	MIT/Global Nuclear Fuels – KazAtom Prom/ULBA Project	EENS
Modular Devices	Test Methodology for Low Cost Radiation Resistance DC-DC Converter	PO
Ocean Optics	Metrology Tools for Surface Profile Measurement	IO
Oxford Superconducting Technology	The Use of TEM and a Newly Developed Precursor-Deposition Method to Improve Fabrication of High Current Superconducting $YBa_2Cu_3O_7$	MA
Psimei Pharmaceuticals	Development of Porphyrins for BNCT	MO
Schering AG	Development of a Non-Iodine Based Radiographic Contrast Agent and a Complementary Monochromator for CT and Planar Imaging Sources	MO
Sub-Terra Sensors	Terrestrial Magnetic Surveyor (TEMASU)	EENS
Symbol Technologies	CMOS Imaging Arrays with Integrated Signal Processing	IO
Technology Commercialization Inc.	Coproduction of Pd-103, Sr-82 and Ge-68 for Commercial Distribution and Medical Applications	MO

Table C2 – CRADA Projects		
SPONSOR	**TITLE**	**DEPARTMENT**
Texaco Group	Nanophase Support Materials as Catalysts for Ultra Deep Sulfur Removal from Crude Oil and Transportation Fuels	EENS
Thorium Power	Radkowsky Thorium Fuel Project	EENS

Table C3 - BSA Patent Portfolio			
Technology Field	**Inventions in Portfolio**	**Inventions Licensed**	**Inventions Commercialized**
Optics	28	25	1
Molecular Biology	25	10	3
Pharmaceuticals	17	11	1
Instrumentation	16	9	3
Materials	16	4	0
Environmental Remediation	11	5	4
Medical Devices	7	1	0
Catalyst	7	0	0
Energy Production	3	2	0
Electron	3	1	1
Total	**133**	**68**	**13**

Table C4 - Examples of Products Marketed Under License From BNL	
PRODUCT	**DEPARTMENT**
Cytoplasmic Bacteriophage Display System	BO
Recombinant Plasmids for Encoding Restriction Enzymes Dpn I and Dpn II	BO
T7 Gene Expression System, Vectors and Protein Products	BO
Appartatus for Purification of Food Wastes	EENS
Fast Repetition Rate Fluorometers for Measuring Fluorescence	EENS
Polyethylene Encapsulation of Radioactive and Mixed Wastes	EENS
Monolithic Amplifier	IO
Surface Profiling Interferometers	IO
Red Blood Cell Labeling Kit for Labeling Whole Blood with Tc-99m	MO

Table C5 – BSA Licensing Revenue ($1000)				
	FY 99	**FY 00**	**FY 01**	**FY 02**
Gross Revenue	2771	2068	2439	2603
Net Revenue	2136	1463	1777	1996

Appendix D: Supplemental Tables

Education Program Participation

Brookhaven National Laboratory Staff Composition

Brookhaven National Laboratory Equal Employment Opportunity Data

Subcontracting and Procurement Data

Small and Disadvantaged Business Procurement Data

Brookhaven National Laboratory

Table D1- Annual Participation In Science Education Programs						
		FY2001			FY 2002	
	Total	Minority	Women	Total	Minority	Women
PRE-COLLEGE PROGRAMS						
Student Programs						
Community Summer Science Program CSSP	34	2	15	27	0	8
Minority High School Apprenticeship Program MHSAP	23	23	15	25	25	
Women in Science and Engineering WISE	31	4	31	31	0	31
Elementary Science Fair	500			510	na	na
Science and Society Essay Contest	0			8	0	3
Maglev Train Contest	200			166	na	na
Bridge Building Contest	300			322	na	na
Robotics Contest				20	na	na
Discovery Tours Grades 1-3	9,079			5367	na	na
Investigations in Science Grades 4-6	5,170			5857	na	na
Inquiries	1,021			741		
Magnets to Go Grades 4-6	7,496			6402	na	na
Museum Summer Camp	na			132	na	na
High School Tours	863			949	na	na
Teacher Programs						
MSTe	215			0		
Quarknet	15			15		
Cosmic Ray Project	15			15		
Discoveries to Go	1,333			0		
Teacher Training	350			20		
Special Programs						
Online Classroom	2			2		
Museum On-Site Programs	401			396		

Table D1- Annual Participation In Science Education Programs

		FY2001			FY 2002	
	Total	**Minority**	**Women**	**Total**	**Minority**	**Women**
Student Programs						
Community College Institute CCI	16	5	8	19	6	9
College Mini-Semester	14	12	8	20	5	13
Energy Research Laboratory Fellowship ERULF	59	7	24	69	24	27
Semester ERULF	5	3	3	14	1	6
Nuclear Chemistry Summer School	12			14	0	6
Pre-Service Teacher PST	6	5	4	11	9	9
Suffolk Comm. College SCCC CO-OP	0	2	2	2	1	1
USSP to the IAEA				6	0	1
BNL-SCCC Environmental Field Program	4			0		
Academic Year Research Interns	1	0	1	1	0	1
Longwood Girls-in-Science Club	40	12	28	0		
Special Programs						
Faculty and Student Teams FaST	0			0		
College Tours	1851					
Faculty Programs						
FaST	0			0		

Table D2 - Brookhaven National Laboratory Staff Composition

	PHD		MS/MA		BS/BA		OTHER		TOTAL	
	#	%	#	%	#	%	#	%	#	%
PROFESSIONAL STAFF Scientists	465	79.1	42	7.1	36	6.1	45	7.7	588	20.3
Engineers	93	18.2	179	35.0	153	29.9	86	16.8	511	17.6
Management & Administrative	61	10.1	148	24.5	152	25.2	242	40.1	603	20.8
Other Professional	4	50.0	2	25.0	1	12.5	1	12.5	8	0.3
SUPPORT STAFF Technicians	0	0.0	17	3.4	66	13.0	424	83.6	507	17.5
All Others	0	0.0	11	1.6	47	6.9	621	91.5	679	23.4
LABORATORY TOTAL	**623**	**21.5**	**399**	**13.8**	**455**	**15.7**	**1419**	**49.0**	**2896**	**100.0**

Table D3 - Brookhaven National Laboratory Equal Employment Opportunity														
OCCUPATIONAL CODES	**TOTAL**		**WHITE**		**MINORITY**									
					TOTAL		**BLACK**		**HISPANIC**		**NATIVE AMERICAN**		**ASIAN/PACIFIC ISLANDER**	
GENDER	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Officials & Managers														
	310	74	289	66	21	8	7	3	4	2	0	0	10	3
	80.7%	19.3%	75.3%	17.2%	5.5%	2.1%	1.8%	0.8%	1.0%	0.5%	0.0%	0.0%	2.6%	0.8%
Professional Staff														
	919	181	707	118	212	63	14	10	25	9	0	0	173	44
Scientists & Engineers	83.5%	16.5%	64.3%	10.7%	19.3%	5.7%	1.3%	0.9%	2.3%	0.8%	0.0%	0.0%	15.7%	4.0%
Management &	57	169	51	146	6	23	4	13	0	5	1	0	1	5
Administrative	25.2%	74.8%	22.6%	64.6%	2.7%	10.2%	1.8%	5.8%	0.0%	2.2%	0.4%	0.0%	0.4%	2.2%
	466	41	416	37	50	4	23	2	16	0	2	0	9	2
Technicians	91.9%	8.1%	82.1%	7.3%	9.9%	0.8%	4.5%	0.4%	3.2%	0.0%	0.4%	0.0%	1.8%	0.4%
All Other														
	402	277	307	183	95	94	62	65	25	22	5	1	3	6
	59.2%	40.8%	45.2%	27.0%	14.0%	13.8%	9.1%	9.6%	3.7%	3.2%	0.7%	0.1%	0.4%	0.9%
	2154	**742**	**1770**	**550**	**384**	**192**	**110**	**93**	**70**	**38**	**8**	**1**	**196**	**60**
Totals	**74.4%**	**25.6%**	**61.1%**	**19.0%**	**13.3%**	**6.6%**	**3.8%**	**3.2%**	**2.4%**	**1.3%**	**0.3%**	**0.03%**	**6.8%**	**2.1%**

Brookhaven National Laboratory

Table D4 - Subcontracting And Procurement			
Dollars in Millions-Obligated [(1)]	**FY 2001**	**FY 2002**	**Estimated FY2003**
Subcontracting and Procurement from:			
Universities	7.9	8.8	7.5
All Others	132.0	166.4	134.7
Transfers to other DOE Facilities	3.0	1.9	2.0
Total External Subcontracts and Procurement	**142.9**	**177.1**	**144.2**
(1)Show total dollars obligated within each fiscal year.			

Table D5 - Small And Disadvantaged Business Procurement		
Dollars in Millions – Budget Authority [(1)]	**FY 2001**	**FY 2002**
Procurement from S&DB	3.99	9.62
Percent of Annual Procurement	4.1	7.6
(1) Show total dollars obligated within each fiscal year.		

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